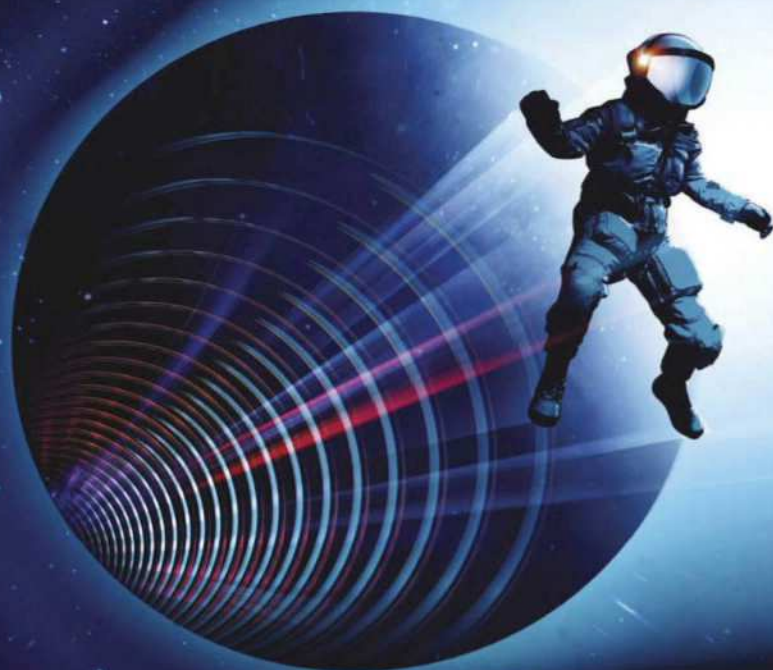


SCIENCE | TECHNOLOGY | HEALTH

# FOCUS

## THROUGH THE WORMHOLE

A TUNNEL BETWEEN GALAXIES EXISTS, WE JUST HAVE TO FIND IT...



**MICHAEL MOSLEY**

Why you don't feel good after exercise

**LIVING WITH CHIMPS**

Jane Goodall on her controversial career

**THOUGHT-CONTROLLED TECH**

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NEWCASTLE Metro Radio Arena	08
MANCHESTER Arena	09
SHEFFIELD FlyDSA Arena	10
PETERBOROUGH Arena	13
LEEDS First Direct Arena	14
BELFAST SSE Arena	15
DUBLIN 3 Arena	16
GLASGOW The SSE Hydro	19
ABERDEEN AECC	20
LIVERPOOL Echo Arena	21
NOTTINGHAM Arena	22
BIRMINGHAM Arena Birmingham	23
LONDON The SSE Arena, Wembley	24
BRIGHTON Brighton Centre	26
BOURNEMOUTH International Centre	27
PLYMOUTH Pavilions	28

## MARCH

CARDIFF Motorpoint Arena Cardiff	01
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An email typically produces 4g of CO<sub>2</sub> emissions → p81

# WELCOME



Over the last few months the country's been having a hard look at the way it treats women. More specifically, corporations in the UK with more than 250 employees have been reporting how much they pay women compared to men. It's an unprecedented endeavour, so naturally the data hasn't been perfect. The reports from each organisation reveal the median hourly pay gap across the entire company, overlooking the differences

within similar positions and leaving out some of the highest and lowest earners. That said, the initial signal is clear: on average women earn 9.7 per cent less than their male colleagues.

So what can we do? BBC staff (whose gender pay gap was 9.3 per cent) have written an open letter to director general Tony Hall asking the organisation to initiate total pay transparency. If it becomes policy, every employee will be able to find out what any other employee is earning. Here at *BBC Focus*, this got us talking. How would we feel if we suddenly knew what everyone else was earning?

Logically speaking, salary transparency seems like the speediest route to balance pay inequality. But instinctively, it's uncomfortable. We're more likely to tell a stranger how many sexual partners we've had than reveal what we're paid, according to a recent survey carried out by University College London. So how can we navigate this tricky route ahead? On p47 Moya Sarner takes a look at what the research reveals about pay transparency and finds out whether it really does work.

*Daniel Bennett*

Daniel Bennett, Editor

## IN THIS ISSUE



### HAYLEY BENNETT

Neural dust could provide the key that enables us to connect up to and control technology with just our thoughts, as Hayley discovers. → p58



### STUART CLARK

Stuart is an astrophysicist and author. He's just the person to introduce the stunning photographs of Jupiter taken by NASA's Juno space probe. → p64



### JANE GOODALL

Over half a century of researching chimpanzees has given Jane a unique insight into not only these mammals' social lives but ours too. → p54

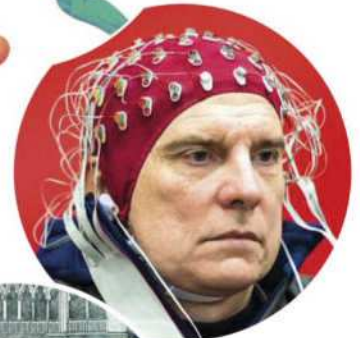
## WHAT WE'VE FOUND OUT THIS MONTH

Life's building blocks may have taken shape in space → p24



Not everyone gets a runner's high → p27

Scientists have created implants that can monitor individual nerve cells → p62



The Alder tree's rot-resistant properties are what inspired the Venetians to expand their city into a lagoon → p95



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# CONTENTS

28



## REGULARS

### 6 Eye opener

Incredible images from around the world.

### 10 Reply

What's been in our inbox this month?

### 13 Discoveries

The biggest science news.

PLUS: Hawking's last theory.

### 27 Michael Mosley

Is runner's high a real thing?

### 28 Innovations

All the best technology and gadget news.

PLUS: Smartwatches go head-to-head.

### 79 Q&A

Your burning science questions answered by our panel of experts.

### 89 Helen Czerski

Helen stares up at the clouds.

### 90 Out there

All the best science books and shows to look forward to.

### 96 Crossword

Get your brain in gear.

### 98 My life scientific

Helen Pilcher talks to Roma Agrawal about why engineers are unsung heroes.

### 52 Subscribe

Get 40% off when you subscribe to *BBC Focus* today!

38







## FEATURES

COVER  
STORY

### Through the wormhole

**38** We find out if we could take a shortcut into another galaxy by plunging through a black hole.

### The science that can close the gender pay gap

**47** Could pay transparency transform our working lives for the better?

### Living with chimps

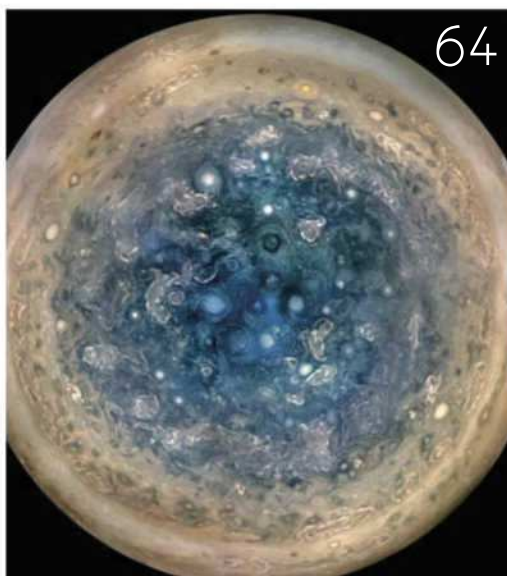
**54** Iconic conservationist Jane Goodall chats to us about chimps, women in science, and why we should look up from our phones.

### Thought-controlled tech

**58** Researchers around the world are building machines that we can control with our minds.

### So long, and thanks for all the pics

**64** The two-year Juno mission is coming to a close. We take a look back over some of its incredible pictures of Jupiter.



## WANT MORE?

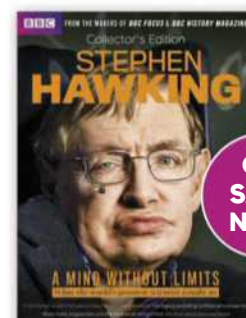
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## SPECIAL ISSUE



### STEPHEN HAWKING: A MIND WITHOUT LIMITS

In this special edition from *BBC Focus* and *BBC History Magazine*, we take a look back over the incredible life and work of Prof Stephen Hawking. [buysubscriptions.com/focuscollection](http://buysubscriptions.com/focuscollection)



## EYE OPENER

# Rainforest recyclers

DANUM VALLEY, BORNEO

As part of the rainforest's vast recycling system, foraging ants will soon find any carcasses and dismantle them at speed. Photographer Nick Garbutt found this newly deceased tarantula on the forest floor in Borneo's Danum Valley, laid it on a piece of white paper, and took these photos over the course of four hours.

When a foraging ant finds a dead animal, she will lay a pheromone trail to guide her nestmates back to the carcass. When the ants arrive, they'll cut off scraps with their jaws and carry them back to their nest.

Ants are responsible for removing more than half the food resources and decaying matter from the rainforest floor, helping to keep the ecosystem healthy. "When we think of scavengers we tend to think about large, dead animals being processed by hyenas, jackals and vultures," says entomologist Prof Adam Hart. "But most of the animal biomass in an ecosystem is in smaller animals, and ants play a crucial role in recycling these creatures."

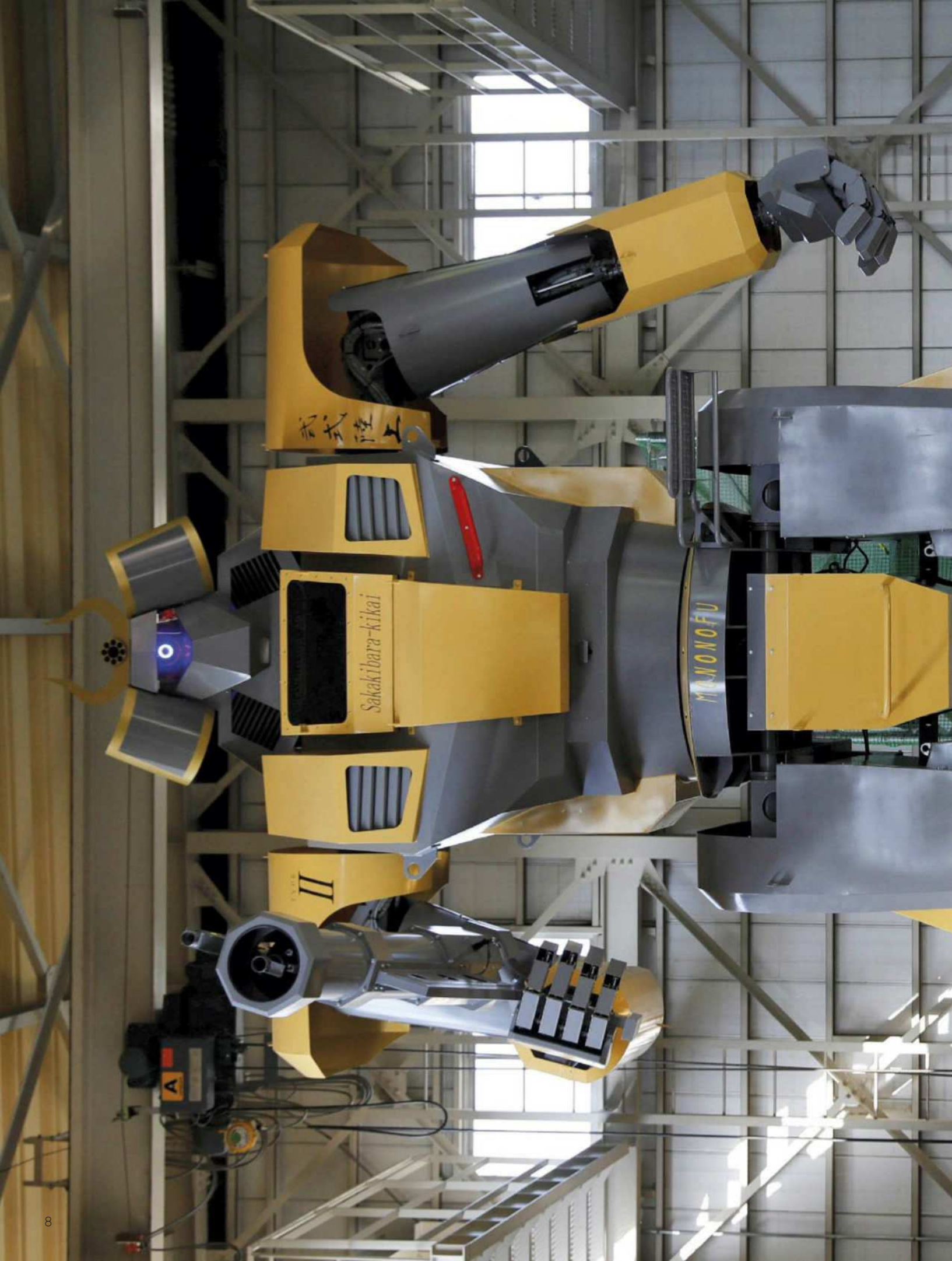
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# Macro machine

SHINTO, JAPAN

As a child, Japanese engineer Masaaki Nagumo watched animated human-controlled robots in battle in the popular Japanese series *Mobile Suit Gundam*. Inspired by the show, he's created LW-Monofu, an 8.5-metre-tall robot that tips the scales at more than seven tonnes.

Climb into LW-Monofu's cockpit, and you'll find monitors and levers that control the robot's arms and legs. It can move its upper body and walk forwards and backwards, but with a top walking speed of less than 1km/h, it's not winning any races. That bazooka-like right arm might come in handy in combat though; it fires sponge balls at around 140km/h (87mph).

Don't expect to see LW-Monofu charging around the Japanese countryside, though. Nagumo accidentally built the robot higher than its warehouse's door, so it can't leave without being dismantled.



# REPLY

Your opinions on science, technology and *BBC Focus*

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## MESSAGE OF THE MONTH

### Clever cocktail

Two articles in your March issue came together to solve two kitchen questions for me in a delicious way.

I love hot chocolate and am sold on the health benefits of turmeric. In Michael Mosley's article on turmeric (March, p28), he reported that cooking with it is much better than taking a supplement. Adding fat and heating it up might make turmeric easier for the body to absorb. I've tried making 'golden milk' with turmeric but it's hard to get the turmeric to dissolve without extra steps.

A few pages later in the issue was Helen Czerski's article on how to get cocoa powder to dissolve to make good hot chocolate (p87). Bingo! I added a teaspoon of turmeric to a tablespoon of cocoa powder in a pan with a little bit of non-dairy coconut creamer (because I am vegan). I slowly squished the powders sideways into the warm creamer as she described and they dissolved together nicely. I added some sweetener and enough almond milk to make a good-sized cup of hot chocolate. It was easy and yummy. Thanks!

Nancy Reed, NY

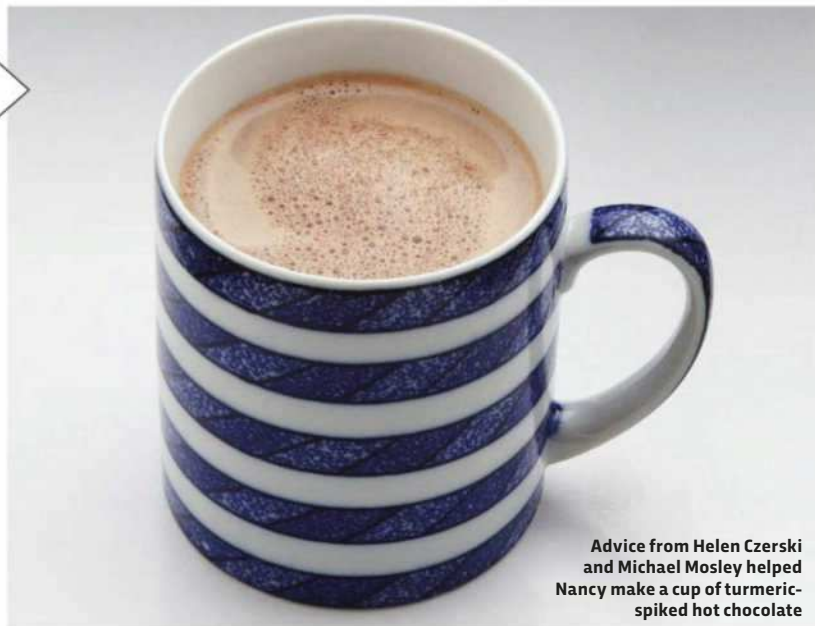
👉 You genius, Nancy! Glad we could help.

– Daniel Bennett, editor

### WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins a bundle of science-themed goodies from Rex London, worth over £50. The stash includes a stylish bamboo travel mug and bento box showing the periodic table, and a world map wall chart and glasses case. [rexlondon.com](http://rexlondon.com)

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Advice from Helen Czerski and Michael Mosley helped Nancy make a cup of turmeric-spiked hot chocolate

### Planetary MOT

Regarding your articles on whether we should intervene and do something directly to counteract climate change (April, p70), I agree with Peter Irvine that we should. If you have an accident and damage your car, you take steps to reduce the risk of it happening again, but you also fix the car. In the same way, we have had an accident with the Earth due to our own ignorance. Therefore, as well as taking steps to prevent further overheating we should fix the Earth and cool it down by geoengineering.

Roy Caswell, Bolton

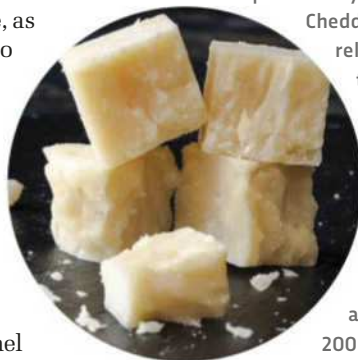
### Cheese it

In response to Michael Mosley's article 'Is it okay to cut out cow's milk?' (May, p27), I find drinking milk and soft

cheeses upsets my digestive system, as does anything with whey in it. However, I do enjoy hard cheeses like Cheddar which does not upset my system. Would eating a reasonable amount of hard cheese help keep up my iodine intake in the same way milk does?

John Newton, via email

👉 The good thing about cheese, particularly hard, mature cheese like Cheddar, is that unlike milk it is relatively low in lactose and therefore unlikely to trigger symptoms in someone with lactose intolerance. Unfortunately, it is not very high in iodine. According to the British Dietetic Association, an adult needs about 150-200 micrograms (mcg) a day of iodine. Below I have listed the sort of amounts you would get in different foods. If you find you're running short, try





topping up with yoghurt or fish (preferably cod or haddock). 100ml cow's milk (50mcg); 100g yoghurt (50mcg); 100g haddock (320mcg); 100g cod (200mcg); 40g hard cheese (15mcg).

– **Dr Michael Mosley, BBC Focus columnist**

### Emotional rollercoaster

The idea that the brain constantly tries to predict what is about to happen and makes preparations, but sometimes gets these wrong (May, p42) is no surprise, and tells us nothing about what emotions actually are. A machine could be made to predict danger and make preparations, but would it care?

Machines and simple animals follow automatic programs, which is fine until the environment changes. Free will and emotions evolved to enable animals to be more adaptable. And you need both. Free will without emotion is no good, you can do what you want but you wouldn't want anything. Emotions and no free will would be a nightmare, you would want things but wouldn't be able to do anything about it.

Which is all interesting but still doesn't shed any light on what emotions actually are. It is

Seaweed and kelp can be a good source of iodine, and often feature in Asian diets

impossible to describe an emotion, except with reference to other emotions, and/or to a being who also experiences emotions. It seems inconceivable that a machine would ever be able to feel annoyed, or jealous, or embarrassed!

Human emotions probably boil down to feeling good or feeling bad, along with all the subtleties around why we feel good or bad. A machine could compute which emotion would be right for a particular situation, but could it ever feel 'good' or 'bad'? Could it suffer? Maybe self-awareness is the key: if an AI could become self-aware, maybe it would be able to suffer. But we could never be sure, because we'd never know exactly what it feels like to be that AI!

Henry Parr, Frome

### Meanwhile over on Twitter...

@Marcuschown "Big cats are attracted to aftershave. Their favourite fragrance is Calvin Klein's Obsession" says @sciencefocus. Surely it should be Lynx!

@allchanges What about Old Mice ?

@paulmurphy68 That's BRUTal!



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# DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

JUNE 2018

EDITED BY JASON GOODYER

PHYSICS

## STEPHEN HAWKING'S FINAL THEORY QUESTIONS THE TRUE NATURE OF THE UNIVERSE

Ten days before his death on 14 March, the famous physicist put the finishing touches on a paper detailing a bold new theory about the origin of the Universe...



“THE NEW THEORY IS BASED  
ON THE SOMEWHAT  
ABSTRACT CONCEPT THAT  
THE UNIVERSE ACTS LIKE A  
VAST HOLOGRAM”

Our Universe is finite and is one of many similar universes, according to Stephen Hawking's final paper on the nature of the cosmos.

The paper, titled *A Smooth Exit From Eternal Inflation?* is the end result of Hawking's long-standing collaboration with Thomas Hertog, a physicist based at the Catholic University of Leuven in Belgium, and was submitted for publication just days before the physicist's death earlier this year.

There are several competing theories regarding exactly how the Universe came to be, but most agree that in the fractions of a second following the Big Bang the Universe expanded incredibly rapidly in all directions, much like a balloon does when it's being blown up. This is known as cosmic inflation and accounts for the fact that the Universe has a large-scale structure that appears to be the same in every direction. There is far less of a consensus, however, on what happened next.

According to the theory of eternal inflation, one of the leading theories, after the Big Bang some pockets of space stopped expanding while others continued. This gave rise to many so-called bubble universes, which are separated from one another by vast areas of expanding space.

In our Universe, expansion ended. This enabled the galaxies and stars to form, but it's just one small pocket of space embedded in a much larger expanding area within which there are countless other bubble universes. According to the theory, the laws of physics in these bubble universes could be different from ours, making them very strange worlds indeed.

But this idea has never sat well with Hawking. “The usual theory of eternal inflation predicts that, globally, our Universe is like an infinite fractal, with a mosaic of different pocket universes, separated by an inflating ocean,” he said. “The local laws of physics and chemistry can differ from one pocket universe to another, which together would form a multiverse. But I have never been a fan of the multiverse. If the scale of different universes in the multiverse is large or infinite the theory can't be tested.”



ABOVE: Prof Stephen Hawking worked with Thomas Hertog (to his left) on his final paper

The new theory is based on the somewhat abstract concept that the Universe acts like a vast hologram. Physical reality in certain 3D spaces can, thanks to some very clever maths, be reduced to 2D projections on a surface, much like a hologram can display a 3D image on a 2D surface.

After hashing through some complicated equations, Hertog and Hawking came to the conclusion that our Universe is finite and far simpler than the infinite fractal structure predicted by the old theory of eternal inflation.

“We predict that our universe, on the largest scales, is reasonably smooth and globally finite. So it's not a fractal structure,” said Hawking. “We're not down to a single, unique Universe, but our findings imply a significant reduction of the multiverse, to a much smaller range of possible universes.” This means it's possible to test the theory through experiment. Hertog believes that primordial gravitational waves, ripples made in space-time by some of the most violent events in the cosmos, may provide a means of doing so.

RIGHT: Eternal inflation enables the possibility that many bubble universes may exist







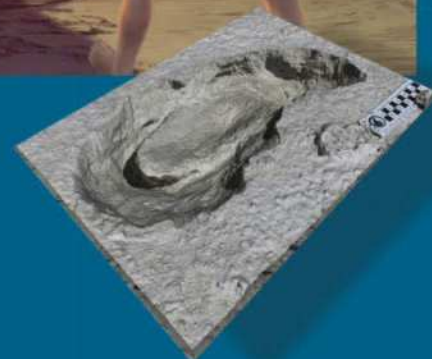
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## ARCHAEOLOGY

# Fossil footprints suggest ancient humans hunted giant sloths



**Ancient tracks found in New Mexico suggest our ancestors hunted giant ground sloths, and that it was something of a spectator sport**



Standing at up to 2.5 metres tall, with thick, muscular legs and sharp wolverine-like claws, the giant ground sloth was not an animal to be trifled with. But it seems that didn't stop ancient humans from hunting them. Researchers at Bournemouth University and the University of Arizona have found a series of footprints indicating that our ancestors once stalked the ferocious animals.

The team found the tracks, which date back around 12,000 years, on a remote salt flat in New Mexico's White Sands National Monument.

"This wasn't just one human footprint and one sloth footprint. Somebody was walking along, purposely putting their feet in the sloth tracks," said the University of Arizona's Prof Vance Holliday. "It's pretty amazing to see that sort of fleeting evidence of behaviour. You don't see that kind of thing very often in the really early archaeological record."

Early humans in North America

were known to hunt mammoths and mastodons but these tracks are the first evidence that they may have hunted giant sloths, the team says.

"We also see human tracks on tip toes approach these circles; was this someone approaching with stealth to deliver a killer blow while the sloth was distracted? We believe so," said the University of Bournemouth's Prof Matthew Bennett. "It was also a family affair, as we see lots of evidence of children's tracks and assembled crowds along the edge of the flat playa. Piecing the puzzle together, we can see how sloths were kept on the playa by a horde of people and distracted by a hunter stalking from behind, while another crept forward to strike the killing blow as the animal turned."



## NEUROSCIENCE

## Fear 'off switch' in mouse brains could lead to new treatments for anxiety disorders

Faced with a potential threat, a mouse will respond in one of three ways: either freezing (making it harder for the predator to detect it), ducking into the nearest shelter, or running for its life. Now, a team at Stanford University School of Medicine has identified two clusters of nerve cells in a mouse's brain that control this response by sending signals to different regions. As similar circuitry is found in human brains, the discovery could potentially lead to new ways of treating phobias, anxiety disorders and post-traumatic stress disorder, they say.

The researchers placed mice into a specially designed tank that simulated the approach of a bird of prey by displaying an expanding dark disc above the mice's heads, representing the shadow of a predator as it swooped overhead. By monitoring the mice's brain activity as the 'predator' attacked, the researchers were able to determine that the ventral midline thalamus, or vMT, fired every time the mice sensed they were in danger. They then traced outputs from the vMT to the basolateral amygdala and the medial

prefrontal cortex. Previous work has shown that the amygdala is involved with the processing of threat detection and fear, and the medial prefrontal cortex is associated with high-level cognitive control and anxiety.

They found that stimulating the amygdala increased the likelihood that the mice froze, while stimulating the medial prefrontal cortex led the mice to stand their ground and act in an uncharacteristically brave manner.

"You could hear their tails thumping against the side of the chamber," said lead researcher Dr Andrew Huberman. "It's the mouse equivalent of slapping and beating your chest and saying, 'Okay, let's fight!'."

As human brains have a structure similar to the vMT, Huberman suspects that people with phobias, constant anxiety or PTSD, malfunctioning circuitry or traumatic episodes may benefit from therapies designed to damp down signalling in the region.

"This opens the door to future work on how to shift us from paralysis and fear to being able to confront challenges in ways that make our lives better," said Huberman.

## IN NUMBERS

86  
MILLION

Number of working days lost annually in the UK due to migraine, as calculated by Lancaster University.

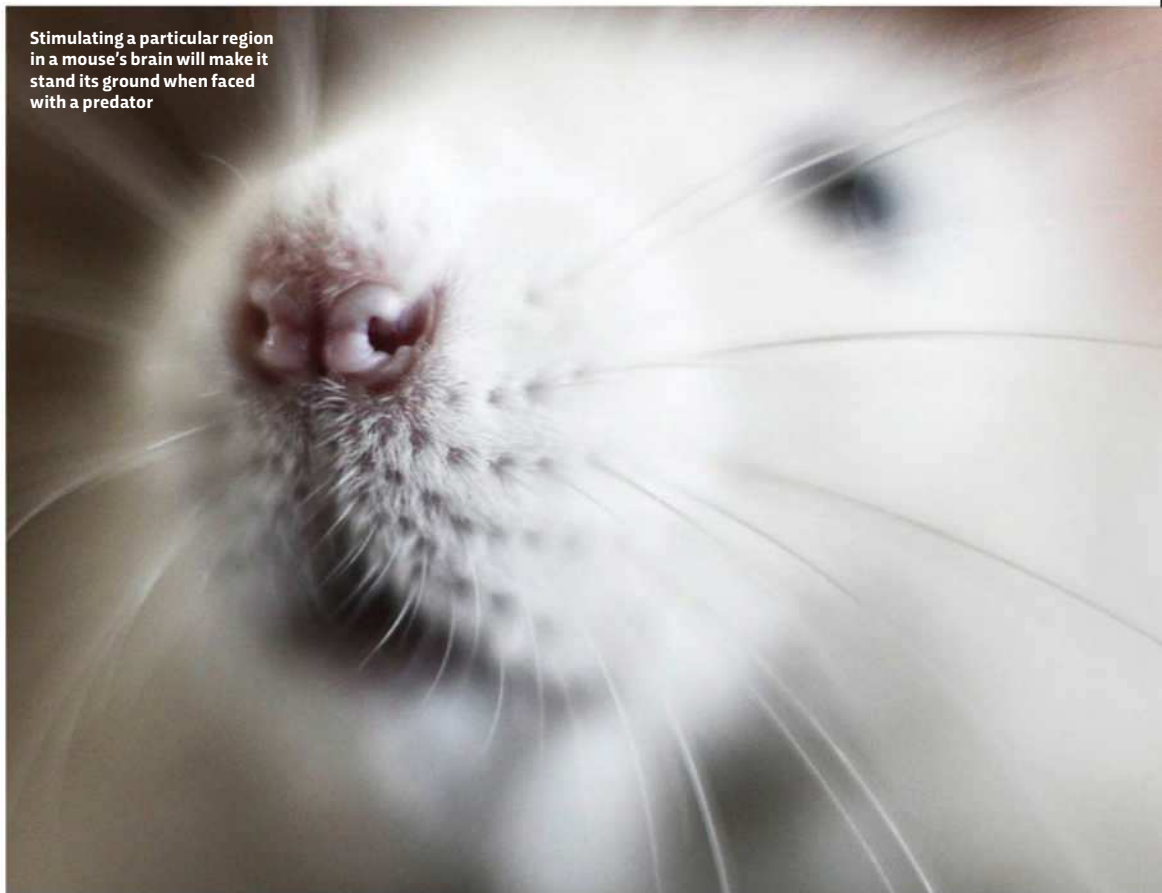
4

The number of academic studies published this month finding that illegal immigration has no effect on violent crime.

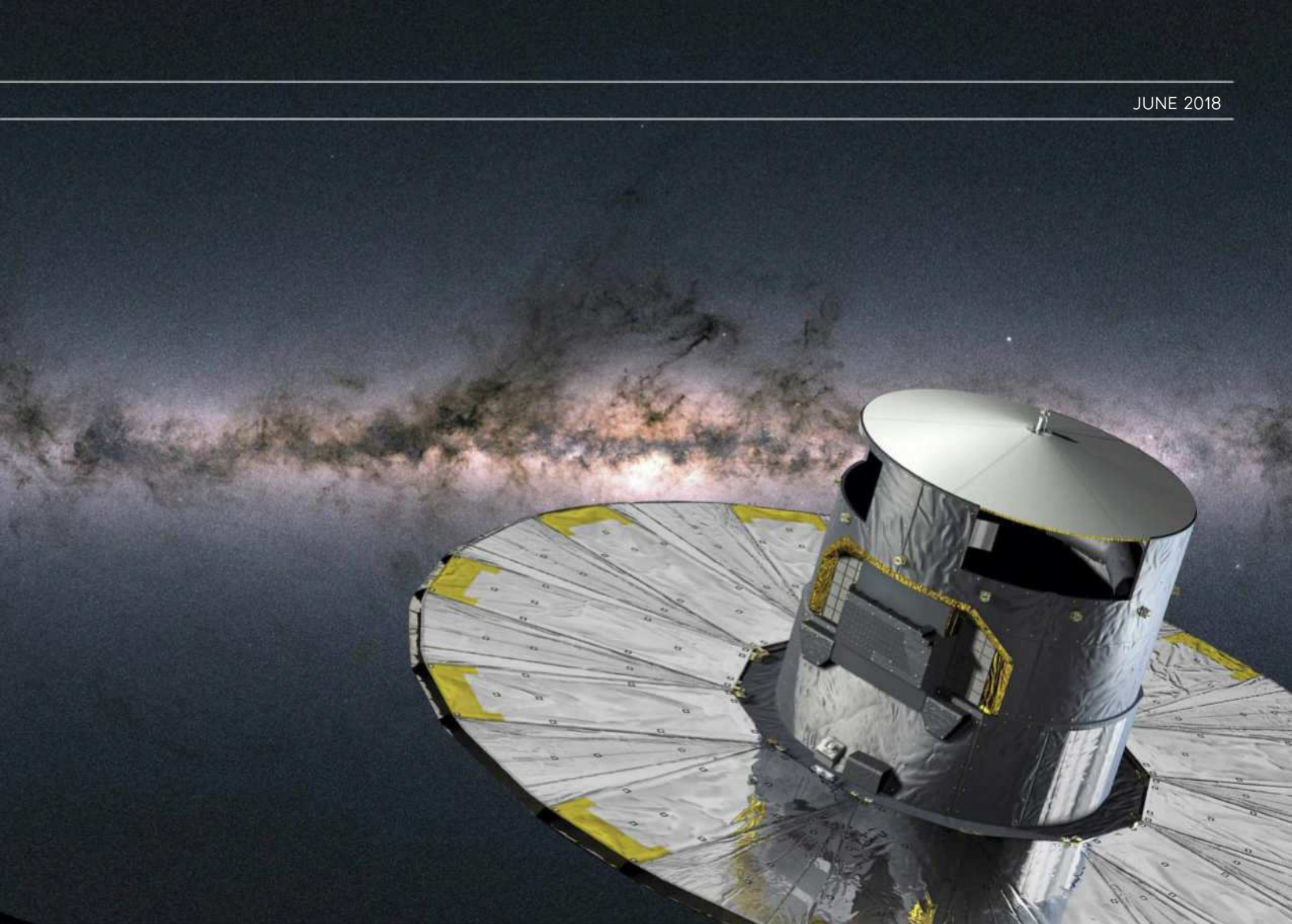
250

The number of people that made up the founding population of Native Americans, as estimated by a genetic study carried out by researchers at the University of Kansas.

Stimulating a particular region in a mouse's brain will make it stand its ground when faced with a predator







## ASTRONOMY

# GAIA SATELLITE CREATES RICHEST STAR MAP TO DATE

It's time to remap the cosmos. ESA's Gaia mission has produced the most detailed picture yet of the night sky, pinpointing the positions of nearly two billion stars.

Launched in December 2013, the Gaia space observatory is creating a three-dimensional map of the Milky Way. After an initial data release in 2016, this second phase covers the period from 25 July 2014 to 23 May 2016, and increases the number of surveyed stars from two million to almost 1.7 billion. It also ramps up the accuracy, with a maximum precision equivalent to someone on the Earth being able to spot a coin on the surface of the Moon.

As well as their positions, Gaia also measured the brightness and colour of most of the stars, the velocity across the sky of more than 1.3 billion of them, the surface temperatures of about 100 million and the effect of interstellar dust on 87

million. It also measured the positions of more than 14,000 asteroids in our Solar System and, much further afield, of half a million quasars – luminous galactic nuclei powered by supermassive black holes.

Astronomers are now eagerly sifting through all this new data. “The new Gaia data are so powerful that exciting results are just jumping at us,” said Antonella Vallenari, one of the lead scientists involved in the project. “It feels like we are inaugurating a new era of galactic archaeology.”

Of particular interest so far are measurements suggesting that fast-moving stars in the Milky Way's outer ‘halo’ region consist of two separate stellar populations that were created through two different processes.

Further observations should shed more light on these stars, and help us piece together how our home galaxy came into being.

**NASA's Gaia space mission is giving us a much clearer picture of the Milky Way**



## RADIATION

# NEW TECHNIQUE REVEALS LEVELS OF HIROSHIMA RADIATION

In the 70-plus years since the US dropped atomic bombs on the Japanese cities of Hiroshima and Nagasaki, several studies have examined the levels of radiation to which victims were exposed, using techniques ranging from long-term studies of mutation in the DNA of survivors, to measuring the luminescence of quartz grains in brick fragments. But now a team at the University of São Paulo (USP) in Brazil has successfully completed the first such study using actual human tissue.

To do this, they employed a technique called ‘electron spin resonance spectrometry’. The research was conducted by postdoctoral researcher Angela Kinoshita, under the supervision of USP’s Prof Oswaldo Baffa, and builds upon 1970s research by Prof Sérgio Mascarenhas, also of the University of São Paulo.

Mascarenhas discovered that exposure to radiation leaves bones weakly magnetised. If levels of background radiation

are known, the extent of this so-called ‘paramagnetism’ can be measured to reveal a bone’s age. This means that if the age of the bone is known, it can be measured to determine how much radiation it has been exposed to.

Some four decades on, with the benefit of more advanced equipment, Baffa and Kinoshita were able to take such readings from tiny fragments of a victim’s jawbone, and determine that the individual had been exposed to approximately 9.46 Grays – almost twice the fatal dose. These findings tally with the results of previous studies, demonstrating the new technique’s potential as a means of triaging possible victims of radiation exposure.

“Imagine someone in New York planting an ordinary bomb with a small amount of radioactive material stuck to the explosive,” said Baffa. “Techniques like this can help identify who has been exposed to radioactive fallout and needs treatment.”



LEFT: Jawbone of victim from Hiroshima

BELOW: A destroyed Hiroshima after the bomb was dropped in 1945





## BIOLOGY

# PATIENTS WITH TYPE O BLOOD MORE LIKELY TO DIE IF INJURED



The O blood type is the most common, and the one that's most frequently requested by hospitals

Accident and trauma victims with type O blood – around 45 per cent of the population – may be at significantly higher risk of dying than people with similar injuries who have less common blood types, according to new research carried out at Tokyo Medical and Dental University Hospital.

“Loss of blood is the leading cause of death in patients with severe trauma, but studies on the association between different blood types and the risk of trauma death have been scarce,” said Dr Wataru Takayama, lead author of the paper in the journal *Critical Care*. “We wanted to test the hypothesis that trauma survival is affected by differences in blood types.”

The team studied the records of the 901 patients treated for severe trauma at two Japanese medical centres in the years 2013 to 2016. They found that

the death rate among patients with type O blood was 28 per cent, compared to just 11 per cent among those with other blood types.

It's believed this may be due to type O blood having lower levels of a blood-clotting agent known as von Willebrand factor.

The findings raise questions about the use of type O blood for blood transfusions when treating trauma patients, but the report's authors urge caution, stressing that it is not yet known whether this applies to all ethnic groups as all 901 patients involved in the research were Japanese. What's more, the study only compared type O to non-type O patients – having blood of types A, B or AB may affect patient survival rates in other ways. More research is therefore needed before hospitals rewrite their trauma treatment rule books, the researchers say.



## NERVOUS PERFORMERS

If the idea of reciting Shakespeare in front of an audience leaves you shaking, relax. A team at Johns Hopkins found that the presence of a paying audience can lift performance quality by 20 per cent.

## THE WELL-EDUCATED

It seems that a great education is good for more than just winning at the pub quiz. A team in Vienna has found a link between education levels and life expectancy. Education gives people better self-control and forward-planning skills, they say.

## GOOD MONTH

## BAD MONTH

## KNOW-IT-ALLS

You don't want to do it like that, you want to do it like this! This is good news for those with smug, superior friends: a study at the University of Michigan has found that know-it-alls often grossly overestimate the extent of their knowledge.

## DESK WORKERS

The brains of those who spend most of their time seated, such as office workers, are smaller than the brains of active people, a UCLA team has found. The medial temporal lobe, a part of the brain associated with fact-based memory, suffers from accelerated age-related atrophy in the sedentary, they say.





## ENVIRONMENT

"There's a big misconception that your plastic bottle gets turned into another plastic bottle"

*Scientists are engineering a plastic-eating enzyme. Portsmouth University's Prof John McGeehan, who is involved in the research, explains how it could help to transform recycling*

ABOVE: Once they are in the environment, plastics can break down into tinier pieces that are harder to clear up and are ingested by animals

RIGHT: Every minute, a million plastic bottles are bought around the world, yet only a small proportion of these are recycled – many end up in the sea

#### Why is plastic such a big environmental problem?

A plastic bottle normally comes from oil and it's made of two components: one is called ethylene glycol, a very common chemical; the other is terephthalic acid. You link those together with an ester bond, and lots of ester bonds in a row generate a long chain – a polyester. Polyethylene terephthalate or PET [a common type of polyester] – the stuff plastic bottles are made of – is incredibly difficult to break down. When chemists made it around 50 years ago, they couldn't have realised it would end up being a scourge in our oceans, lasting for hundreds of years.

#### Where was the plastic-eating enzyme discovered?

In 2016, a Japanese group spectacularly found bacteria in a recycling dump that were essentially living off the plastic, digesting it. What we think has happened is that these bacteria swapped eating natural polyesters for human-made ones, just by mutating one of the enzymes they were making.

#### How did you study the enzyme?

We took the gene for this enzyme and made lots in the lab. We took it to the Diamond Light Source, a massive X-ray microscope, and were able to

generate a beautiful 3D structure. That allowed us to compare it.

There's a polyester on plant leaves called cutin that's really similar to some human-made things. It is as if the enzyme [in the bacteria] has evolved from a cutin-digesting enzyme and then became a plastic-digesting enzyme just by changing the shape of its surface a little bit. Getting the 3D structure helps you see how the enzyme works: it breaks the bonds and turns those long chains into their original building blocks.

#### Why engineer a better version of this enzyme?

It's incredible that bacteria evolved to do this, but the enzyme is still quite slow. It takes weeks for these processes to happen. If you're going to make it a recycling solution, then you have to get those times down to hours in order to be economically viable.

#### How would the enzyme be used in recycling?

There's a big misconception that when you throw your plastic bottle into a recycling bin, it gets turned into another plastic bottle. That rarely happens because when you make it into plastic pellets during the recycling process, it loses some





of its properties and you have to then use it for a lower-value material, like a fibre for clothing or carpet. Eventually, it's effectively worthless and ends up in landfill or being incinerated. This releases CO<sub>2</sub>, which is not good either.

Our idea would be that you have a large vat of plastic bottles, pour the enzyme solution in and digest it to its original building blocks. That would allow us to remake the plastic from scratch, basically closing the loop on the process and making it 100 per cent recyclable. That would be our goal.



#### DIGESTED READ

A species of bacteria has been found in a rubbish dump that can digest plastic into its original building blocks. It can do this because one of its enzymes has mutated. Scientists think that if we created large amounts of this enzyme, we could use it to break down plastics.

## THEY DID WHAT?!



## ORANGUTANS SIGNED UP TO 'TINDER FOR APES'

### What did they do?

A team at the Apennine Primate Park in the Netherlands showed Samboja, an 11-year-old female orangutan, pictures of potential mates on a steel-reinforced touchscreen computer. The images had been gathered from an international ape-breeding programme.

### Why did they do that?

Since the male partner could come from any number of zoos from around the world, the researchers hoped that 'Tinder for apes' would enable them to increase their chances of setting up a successful breeding encounter.

### What did they find?

Although the technique showed promise when trialled on a pair of older orangutans, the tablet didn't hold up to Samboja's rough treatment – she promptly smashed the device shortly after being given it. The team is now working on putting together a more robust device for a second attempt at getting her to swipe right.



## ZOOLOGY

# THREE NEW RAINBOW CHAMELEON SPECIES DISCOVERED

More than 420 reptile species live in the mountains of Madagascar, but an expedition carried out by researchers from the Zoologische Staatssammlung in Munich has yielded a surprise: three new brightly coloured species of chameleon.

The rainbow-hued *Calumma uetzi* was found in the remote mountains on northern Madagascar and is at its most impressive when trying to attract a mate. The males turn a flashy shade of yellow, streaked with violet and red, and if the female is unimpressed, she'll darken her own skin to almost black.

Females from another new species, *Calumma juliae*, were found in a threatened 15-hectare forest fragment beside one of the island's main roads.

"We hope that this area can be protected as soon as possible," said researcher David Prötzel. "Recent imagery from Google Earth shows that, since our discovery of this

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"THE MALES  
TURN A  
FLASHY  
SHADE OF  
YELLOW,  
STREAKED  
WITH VIOLET  
AND RED"

chameleon just two years ago, a significant area of its tiny home has already been lost to deforestation."

The third species is called *Calumma lefona*, and so far, only a single male has been found. Through X-ray scanning, the researchers found a large hole in the roof of its skull, directly over the brain. A similar hole has been seen in six other chameleon species, all of which live more than 1,000m above sea level. Researchers aren't sure exactly what the hole is for, but they think it might help the chameleon regulate its temperature.

"Based on everything we know about these species, they all have very small distribution ranges," said Dr Frank Glaw, head of the institute's Herpetology Section. "But many new protected areas are now being established in Madagascar, which will certainly be important for the future of Madagascar's unique diversity."



*Calumma uetzi* is one of three new species of chameleon discovered in Madagascar

## MEDICINE

## THE MALE PILL... WITH NO SIDE EFFECTS

A new contraceptive pill is being developed. So far, it seems to be free from side effects – and it's for men, not women. The drug, named EP055, contains a protein that binds to the surface of the sperm and slows those little swimmers down.

"Simply put, the compound turns off the sperm's ability to swim, significantly limiting fertilisation capabilities," said lead researcher Michael O'Rand. "This makes EP055 an ideal candidate for non-hormonal male contraception."

The scientists gave macaque monkeys high-dose intravenous infusions of the compound. Thirty hours after the infusion, the researchers found no indication of normal sperm movement in any of the macaques, and they didn't observe any physical side effects.

Around three weeks later, the macaques' sperm were moving normally, although it took them a little longer to get back to full speed. The researchers suggest that this treatment could provide a contraceptive window effective 24 to 48 hours after administration of the drug.

The researchers say the next stage is to conduct a mating trial with the macaques, to measure the compound's effectiveness against pregnancy. They have also begun testing the compound in pill form but it is as yet unclear how long it'll be before the drug becomes publicly available.



FRANK CLAW/ZSM CMU, GETTY, NASA

## ASTRONOMY

## SCIENTISTS PROVE URANUS SMELLS LIKE ROTTEN EGGS

If we ever master space tourism, Uranus is unlikely to become a favourite holiday destination. Researchers have learned that its upper atmosphere is permeated by hydrogen sulphide – the gas that gives rotten eggs their distinctive stench.

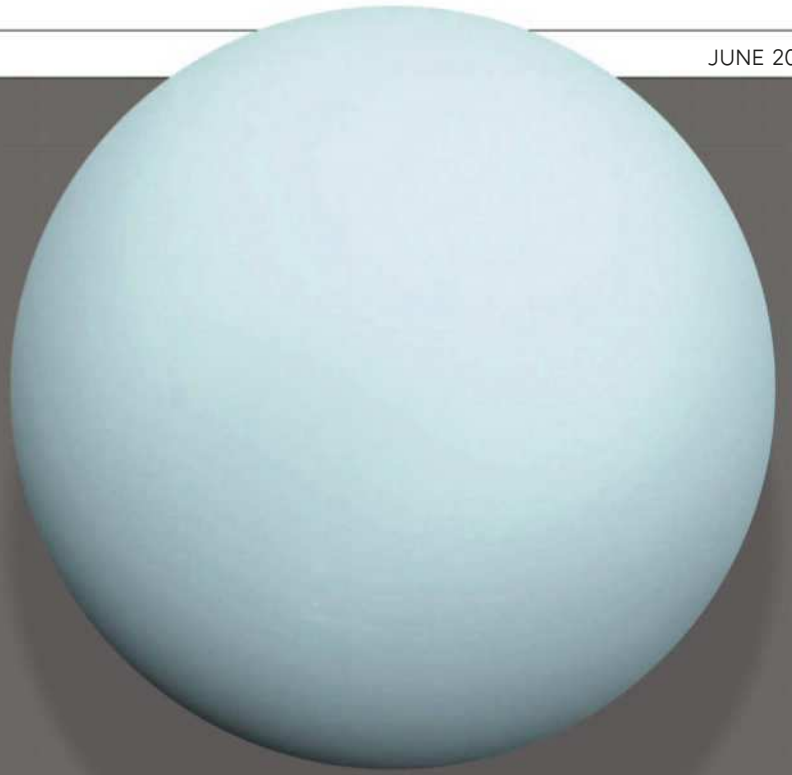
A team of global researchers led by Prof Patrick Irwin from the University of Oxford used the eight-metre Gemini North Telescope on Hawaii's Mauna Kea volcano to peer into the clouds that enshroud the planet. By using infrared spectroscopy, the study of how light and matter interact, they were able to determine the chemical composition of the gases that make up the clouds.

"If an unfortunate human were ever to descend through Uranus's clouds, they would be met with very unpleasant and odiferous conditions," said Irwin. "But that's not the worst of it. 'Suffocation and exposure in the negative 200°C atmosphere made of mostly hydrogen, helium and methane would take its toll long before the smell.'"

Nose-wrinkling smell aside, these new findings reveal information about the early history of our Solar System. We now know that the upper surfaces of the clouds around Uranus differ from those of Jupiter and Saturn – the bulk of these gas giants' clouds are comprised of frozen ammonia. These differences in atmospheric composition were likely imprinted during the formation of these planets.

"As you go further away from the Sun it gets colder, so you get more and more things freezing the further you go. So during the formation of the planets, first you get rocks condensing, then you get water condensing, then ammonia, then hydrogen sulphide," said Irwin. "So the fact that Uranus has more hydrogen sulphide than ammonia means that it must've formed somewhere cold enough that both ammonia and hydrogen sulphide were in their solid form."

There's strong evidence that our Solar System's giant planets have migrated from where they were originally formed. This new information means that Uranus was formed somewhere colder than Jupiter and Saturn, showing that those planets have kept their relative positions.





## SPACE

# BUILDING BLOCKS FOR LIFE CAN FORM IN SPACE

How life came into existence is one of science's greatest mysteries, but a new experiment at the American Institute of Physics suggests that a handful of basic elements and some radiation might be all you need.

A paper in the *Journal Of Chemical Physics* describes how researchers working in cryogenic conditions coated ice with molecules of carbon dioxide, methane and ammonia, and then exposed the ice to a stream of low-energy electrons, or LEEs. This mimics conditions in space, where such basic molecules can be

“AMINO ACIDS  
MAY HAVE  
FORMED IN  
SPACE OVER  
LONG PERIODS  
OF TIME, AND  
THEN BEEN  
DELIVERED TO  
OUR PLANET BY  
A COMET OR  
METEORITE”

detected in the ice found on bodies such as comets or moons, where they are subject to bombardment by various forms of radiation including gamma rays, X-rays, LEEs and solar wind particles.

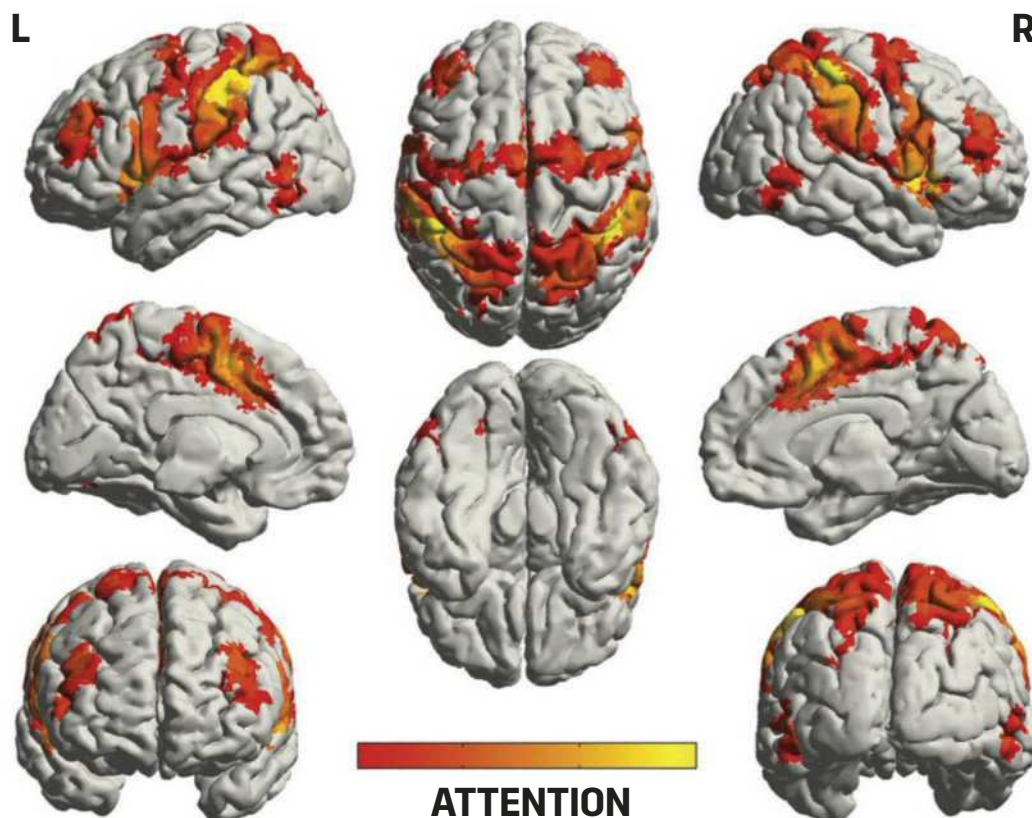
Following the LEE onslaught, the researchers used a spectrometry technique called ‘temperature programmed desorption’ to determine the effects of the radiation, and found that the simple molecules had combined to form glycine, which is an amino acid comprised of hydrogen, carbon, nitrogen and oxygen.

The research suggests that rather than forming here on Earth, amino acids – the building blocks of life – may have formed in space over long periods of time, and then been delivered to our planet by a comet or meteorite impact.

The same team had previously shown that simple molecules in similar conditions could combine to form ethanol, the intoxicating substance found in alcoholic drinks, but glycine is far more complex.

“You just need the right combination of ingredients,” said Michael A Huels, author of the paper. “These molecules can combine, they can chemically react, under the right conditions, to form larger molecules which then give rise to the bigger biomolecules we see in cells like components of proteins, RNA or DNA.”

The experiment by the team at the American Institute of Physics mimicked the conditions found in space



The salience network, the part of the brain that determines what we attend to, is highlighted here in red and orange. It can be fired up with favourite music

## HEALTH

# 'AWESOME MIXES' POINT TO ALZHEIMER'S TREATMENT

Some songs feel like they've been written just for you. They might send a shiver down your spine, give you goosebumps or even move you to tears. Songs like these seem to reach inside you and touch something that nothing else can. And for that very reason, they might be able to treat some of the symptoms of Alzheimer's disease.

"People with dementia are confronted by a world that's unfamiliar to them, which causes disorientation and anxiety," said Jeff Anderson, who, along with his colleagues at the University of Utah Health, is investigating the potential for music-based treatments for Alzheimer's. A recent study by the team suggests that songs a dementia sufferer finds emotionally resonant may alleviate their anxiety by increasing brain activity.

Songs that provoke an emotional response tap into the brain's salience network. This is the part of the brain that chooses which stimuli are worthy of attention, and happens to be one of the

few regions unaffected by Alzheimer's. The study suggests that firing up the salience network with an 'awesome mix' of personally meaningful music seems to kick-start neighbouring regions of the brain that have been ravaged by the disease.

With the help of brain scans, the researchers found that patients listening to their personal soundtrack exhibited significantly higher functional connectivity in the visual, salience and executive networks, and the cerebellar and corticocerebellar network pair, compared to patients scanned in silence.

The authors point out that the small sample size of 17 patients and limited scope of the research mean the results are not conclusive.

"No one's saying playing music will be a cure for Alzheimer's," said Anderson. "But it might make the symptoms more manageable, decrease the cost of care and improve a patient's quality of life."

## THINGS WE LEARNT THIS MONTH

### HORSES CAN READ AND REMEMBER HUMAN EMOTIONS

Why the long face? Horses respond more positively to people that they have previously seen smiling, and more cautiously to those they have previously seen scowling, psychologists at the Universities of Sussex and Portsmouth have found.

### CHILDREN ARE FITTER THAN TOP ENDURANCE ATHLETES

A study at France's Université Clermont Auvergne, has found that children aged between 8 and 12 years old recover from aerobic exercise more quickly and efficiently than highly trained adult endurance athletes.

### MEMBERS OF AN AMAZONIAN TRIBE COMMUNICATE BY DRUMMING

The Bora, indigenous people living in the Peruvian and Colombian Amazon, use manguare drums to communicate with other members of the tribe up to 20km away, a team at the Max Planck Institute has found.



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# "IS 'RUNNER'S HIGH' A REAL THING?"



**DR MICHAEL MOSLEY**

**BBC TWO** Michael is a science writer and broadcaster, who presents *Trust Me, I'm A Doctor* on BBC Two. His latest book is *The Clever Guts Diet* (£8.99, Short Books).



**S**pring is the time when fair-weather runners like me pull our trainers out of hibernation, dust them down and reluctantly start running again. I say 'reluctantly' because I don't enjoy running. I do it because I realise it is good for my lungs, my heart and my brain. I also do it because I am worried that soon I won't be able to keep up with my wife. But I don't, at any point, get pleasure from it. I certainly don't experience the intense pleasure that many avid runners describe as 'runner's high'.

I was curious about what was going on, so as part of a recent programme for BBC One, *The Truth About Getting Fit*, I decided to find out more.

For a long time, the positive feelings that runners describe has been put down to endorphins. These are peptides that our bodies produce which activate opioid receptors in the brain. But physiologist Dr Saoirse O'Sullivan believes a different brain signal may be responsible: a class of chemicals called endocannabinoids. These molecules are neurotransmitters that are similar in structure to the main chemical in cannabis. They bind

to cannabinoid receptors throughout the body, including the brain.

To see if endocannabinoids really do rise in the blood of running enthusiasts, we asked O'Sullivan to help us do an experiment which, as far as we could find out, had never been done before. We got a small group of enthusiasts to go for a short run, only half an hour, outdoors. Previous experiments have involved much longer runs in a lab setting.

So what did we find? Well, once their blood was analysed it was clear that even a short run had had a striking effect. "When you came back from the run, you had, on average, 30 per cent more endocannabinoids in your blood than you did before you set off," O'Sullivan told our volunteers. "So that exercise, short though it was, really does seem to have led to a big increase in endocannabinoids."

One of our runners, a woman who suffers from severe bouts of depression, had a particularly marked response. She is aware of the profound

effect running has on her mood and has been using it as a form of self-medication for some years now. She is a keen marathon runner and is now progressing to running ultra marathons.

So even a short, easy run can bring some people a naturally produced chemical high. But why do we have this system at all? O'Sullivan believes the release of endocannabinoids may be a way for our bodies to encourage us to keep fit. "We know that we're mentally and physically healthier when we exercise. So the body having an immediate reward system for exercise would seem like a good evolutionary thing," she says.

That still doesn't explain why some people get a runner's high while others don't. The next step would be to take a group of people who don't enjoy running, like me, make us run and see what effect, if any, that has on our endocannabinoid levels. It could be we don't produce as much, it could be we don't have such sensitive receptors, or it could be we don't push ourselves hard. I'm up for finding out. Any other exercise sloths care to join me? **Q**

According to O'Sullivan, a 30 per cent increase in endocannabinoids seems to be enough to produce a mood-altering effect.



# INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

JUNE 2018

EDITED BY HELEN GLENNY



## GOING SUPERSONIC

When Chuck Yeager broke the sound barrier in the Bell X-1 in 1947, a sonic boom rang out that battered the eardrums of anyone underneath the plane's 20-second supersonic flight path. Now, NASA has just announced funding for its latest X-plane, a commercial jet capable of flying at those same supersonic speeds (faster than the speed of sound), without the disturbing the peace below.

NASA has awarded Lockheed Martin a \$247.5m (£183m approx) contract to build a working example of a prototype it's been working on for a few years: the Low Boom Flight Demonstrator. It has a long, pointy nose and

small, aerodynamic wings, which should minimise the pressure waves that create the noise at supersonic speeds. NASA plans to start flying the plane by 2022, with testing over highly populated areas completed by 2025.

If successful, it won't be the first commercial supersonic jet. Concorde began taking passengers in 1976, but it was soon banned from flying supersonic over land in the USA and Europe because of the noise it created. Lockheed Martin says this new X-plane won't be completely silent – the shockwaves should sound more like a car door closing than a deafening boom.



602

A long nose and small wings, as seen in this artist's impression, cut down on noise-inducing pressure waves

Great balls of fire! We like the look of NASA's new X-plane!





## WANTED

<p><b>1</b> <b>EXPENSIVE AUTOGRAPHS</b> If your hand gets tired signing autographs for adoring fans, then you might be able to afford this signing machine. Each of these machines has 585 moving parts that have been assembled by hand and mechanically coded for the owner. <b>Jaquet Droz Signing Machine</b> \$367,500 (approx £267,000), <a href="http://jaquet-droz.com">jaquet-droz.com</a></p>	<p><b>2</b> <b>BROWSING BREAK</b> Need to stop the kids from scrolling through social media late at night? This small cube plugs into your router and manages the times your devices can access Wi-Fi and mobile data, and blocks your choice of nefarious websites. <b>Haandle</b> £89.99, <a href="http://haandle.com">haandle.com</a></p>	<p><b>3</b> <b>ROASTED TO PERFECTION</b> We'll jump at any gadget that'll help us get a juicy steak. Meater is a smart thermometer that connects to an app on your phone. It will tell you when the meat is perfectly cooked and how long you should let it rest before tucking in. <b>Meater</b> £79, <a href="http://meater.com">meater.com</a></p>
<p><b>4</b> <b>RUN YOUR CITY</b> Adidas has released the New York version of their 'Made for' series, created by the Adidas Speedfactory robots. They're tailored for streets of the Big Apple (expertly handling abrupt 90° corners), and the design is driven by data from local runners. <b>Adidas AM4NYC</b> £159.95, <a href="http://adidas.com">adidas.com</a></p>	<p><b>5</b> <b>GONE FOR GOOD</b> Personal info can often be retrieved off scrapped computers, even after you've done your best to delete it. RedKey securely and permanently wipes your data: just plug it in to a USB port, switch on the power, and the wipe will start. <b>RedKey</b> £62, <a href="http://redkeyusb.com">redkeyusb.com</a></p>	<p><b>6</b> <b>ENDLESS POSSIBILITIES</b> With this desktop laser cutter and engraver, you can 'print' yourself a custom leather satchel, engrave a skin for your laptop, or even create a drone with dual rubber band gatling guns, all from the comfort of your desk. <b>Glowforge</b> \$2,500 (approx £1,850), <a href="http://glowforge.com">glowforge.com</a></p>

7

## BURST THE BUBBLE

In the Netherlands, 1.5 million kilograms of gum ends up stuck to the pavement every year. A group of companies is pulling that gum up off the streets, and turning it into pairs of shoes.

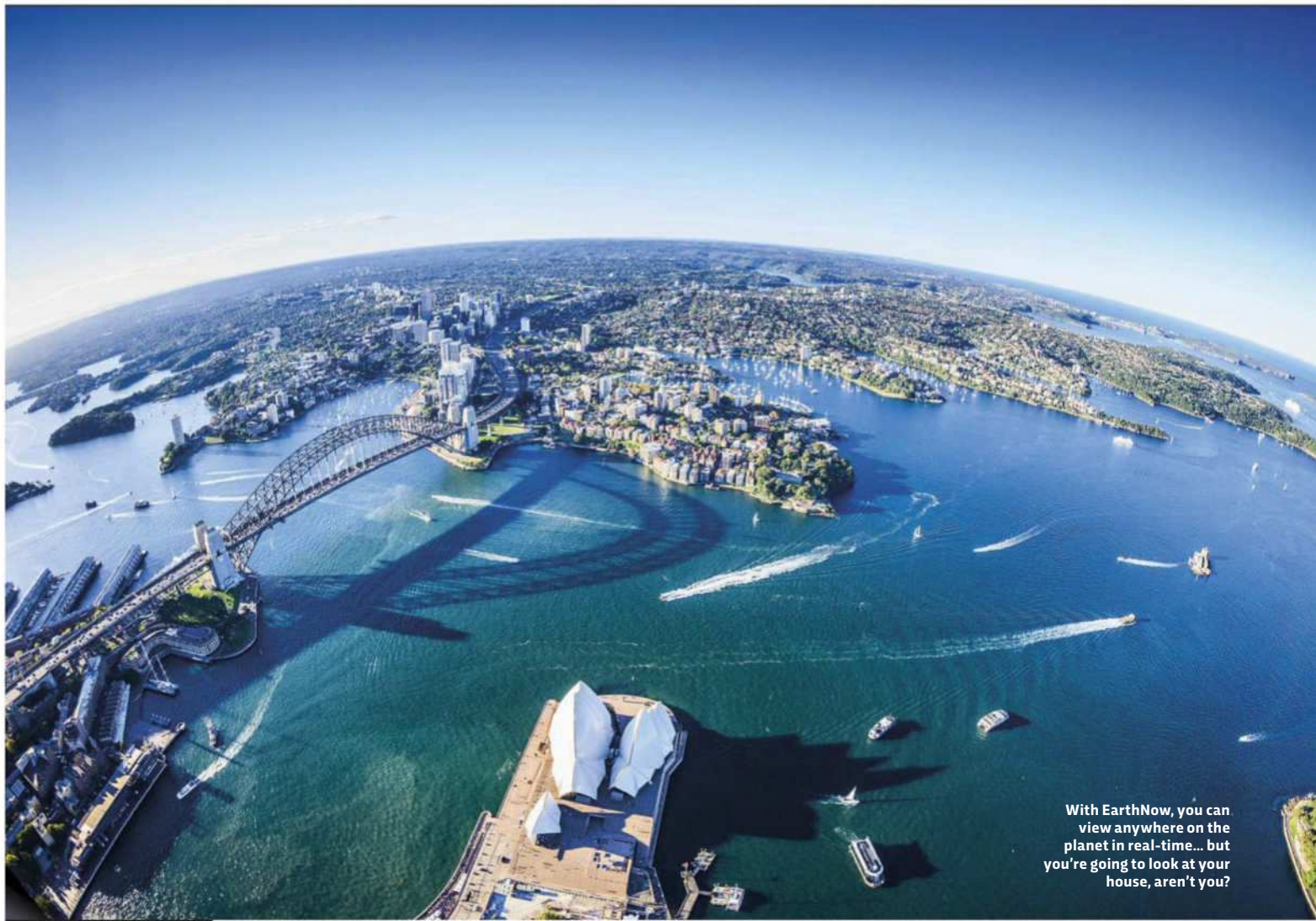
Gumdrop, a Dutch sustainability company, has invented a compound called Gum-Tec, 20 per cent of which is made from gum prised from the streets of Amsterdam. They've collaborated with marketing group Iamsterdam and designer Explicit Wear to create GumShoes, which come in bubblegum pink (of course), as well as a more muted black. A kilogram of gum is used in every four pairs of shoes.

To celebrate GumShoe's origins, each sole has an Amsterdam street map printed in its tread, and the companies are hoping to expand the project to other major cities. "By looking at waste differently, we can find innovative solutions that will bring change to help keep our planet clean," said Anna Bullus, designer at Gum-Tec.

*GumShoe*

€190 (approx £170), [gumshoe.amsterdam](http://gumshoe.amsterdam)





With EarthNow, you can view anywhere on the planet in real-time... but you're going to look at your house, aren't you?

## TECHNOLOGY

# BILL GATES BACKS PLAN TO STREAM EARTH IN REAL-TIME

Want to stream real-time video of wildebeest migrating across the Serengeti, a tropical storm picking up speed in the Pacific, or the long line of traffic you're sitting in? That's the idea behind EarthNow, a company that's recently received backing from Microsoft founder Bill Gates and Softbank CEO Masayoshi Son.

According to EarthNow's founder and CEO Russell Hannigan, "EarthNow is ambitious and unprecedented, but our objective is simple; we want to connect you visually with Earth in real-time. We believe the ability to see and understand the Earth live and unfiltered will help all of us better appreciate and ultimately care for our one and only home."

EarthNow cites a tonne of possible positive applications, like catching illegal fisherman, detecting forest fires as they start, tracking whale

migrations, observing conflict zones and providing on-demand data about crop health. Initially available to governments and enterprises, EarthNow also promises mass market applications that can be accessed from smartphones. "With EarthNow, we will all become virtual astronauts," said Hannigan.

The livestream will come from a large group of satellites, each equipped with an unprecedented amount of onboard processing power. The resolution won't be groundbreaking: you'll be able to see cars and trucks, but you won't be able to identify makes or models. You'll be able to see crowds of people, but individuals aren't big enough to show up. Still, the 'live' aspect of the stream is exciting. "With existing systems, users can see only what has happened in the past. With EarthNow's constellation of satellites, you will see events unfold as they happen in real-time," said Hannigan.

## ROBOTS

## JAPAN TO EMPLOY ROBOT BUILDERS

It takes half a million human hours to build a typical Tokyo skyscraper, and Japan's labour crisis is making that a difficult feat. Now, though, Shimizu Corporation is developing robots to take care of as many of those hours as possible.

At the Robot Laboratory in Tokyo, Shimizu Corporation is testing three new machines. The Robo-Welder has a robotic arm that it uses to weld steel, and the Robo-Buddy is a multi-purpose robot that can install ceiling panels and construct floors. The third robot, Robo-Carrier, can lug one ton of plasterboard to a designated location, using lasers to navigate and recognise obstacles. Unfortunately, building site

regulations mean that Robo-Carrier can only work on sites at nights and during the weekend.

Robots are a feature in most types of manufacturing, with the automobile industry now using one robot for every five human workers. Yet construction has always been resistant to automation, largely because building sites are harder to navigate than factory floors. Although the robots will save thousands of human hours, they can only take on a small fraction of the work on a typical high-rise.

Shimizu's robots will be deployed for the first time at a high-rise building site in Osaka this autumn, and they'll start work on several large construction sites in Tokyo in 2019.

Robo-Welder is on hand to help with Japan's labour shortage



GETTY, PRESS ASSOCIATION

## TECH BYTES

## THICK AS A BRICK

A new robot called the Hadrian X (below) can complete the brickwork on a home in just two days, laying over 1,000 bricks per hour. Its creator, EY-Parthenon, suggests there's enough planned brickwork in the world for 150,000 Hadrian X robots.



## DON'T STIR, STIRACLE

Stiracle, a little platform that could be installed on coffee shop counters, spins your coffee to mix in the milk and sugar. Every day, 400 million stir sticks are used, so the Stiracle could be a fun way to cut down on waste. Sweet!

## FURNITURE FAIL

Don't dread the robot takeover: they'll probably spend all their time assembling furniture. A two-armed robot recently took 20 minutes and 19 seconds to assemble an IKEA chair; a task that humans usually manage in 10-15 minutes. Never mind, eh?



# HEAD TO HEAD: FITNESS WATCHES

Covering everything from skiing to parachuting, these feature-packed watches pump out enough data to overhaul your fitness regimen. **Helen Glenny** puts their claims to the test...

Hefty, high-end fitness watches don't just tell you how far you've run. They can now tell you how much altitude you've gained, how long you've spent dreaming and critique your golf swing. They can track heart rate at your wrist, eliminating the need for a sweaty chest strap, and provide you with round-the-clock data. With so

many good, low-cost fitness trackers available, we wanted to find out whether expensive models, with all their extras, are worth the price. We pit Garmin Fenix 5, a multisport model from the king of fitness watches, against the Suunto Spartan Sport Wrist HR Baro, a feature-packed option from a stylish up-and-comer.

## WHAT YOU NEED TO KNOW

### HOW OPTICAL HEART-RATE SENSORS WORK

Wrist heart-rate sensors use optics to measure your pulse. Blood absorbs a lot of light, so fluctuations in light levels can be used to measure the rhythm of the blood flowing through your arteries and thus your heart rate.

### DO THEY REALLY WORK?

Heart-rate tracking at the wrist is less accurate than chest strap measurements – both Garmin and Suunto readily admit this. Steve LeBoeuf, CEO of Valencell, the company that supplies Suunto's wrist tech, said in 2015 that "the wrist is one of the worst places for accurate [optical] monitoring of heart rate because of the much higher optical noise created in that region (muscle, tendon, bone, etc.)." For the benefits of all-day tracking, you need to accept a small degree of inaccuracy.

### WHY IS IT IMPORTANT?

Your heart rate is important for a lot of fitness metrics, one of which is VO<sub>2</sub>max – how much oxygen you can use during exercise. To measure it, you need a lab, a treadmill and the motivation to run until you can't stand. Instead, these watches estimate VO<sub>2</sub>max based on your heart rate and your speed. The calculations work well, as long as your heart-rate measurement is accurate.

### HOW WE TESTED

I focused on the running functions, taking both watches on a 13km (8-mile) road run and a 16km (10-mile) off-road run, testing GPS accuracy, navigation, heart-rate and VO<sub>2</sub>max measurements. I did a few laps around the local mountain-bike park to see how they fare under dense tree cover. To test comfort, all-day heart-rate tracking, step counting and sleep monitoring, I wore each watch continuously for three days.

STEVESAYERS/THE SECRET STUDIO

## WATCH SPECIFICATIONS

WATCH	GARMIN FENIX 5	SUUNTO SPARTAN SPORT WRIST HR BARO
WRIST HR	YES	YES
STEPS	YES	YES
TOUCHSCREEN	NO	YES
TOPO MAPS	YES	NO
BATTERY	24HR GPS/14 DAYS POWER SAVE	18HR GPS/10 DAYS POWER SAVE
WATER RESISTANCE	TO 100M	TO 100M
WEIGHT	85G	74G
VO <sub>2</sub> MAX ESTIMATOR	YES	YES
RECOVERY ADVISOR	YES	YES



## GARMIN FENIX 5

With five buttons and no touchscreen, it takes time to learn how to access all of the Fenix 5's features. After some frustrated fiddling on my first day, the screen flashed 'high stress' and offered me a one-minute breathing exercise.

The Fenix takes a minute to find a GPS signal, which is unfortunate if it's 10°C outside and you run in shorts. But the navigation is exceptional – I entered my start point and how far I wanted to run, and the Garmin Connect app created a route based on popular runs in my area. The watch shows the route outline with no side roads or landmarks, so it's easy to take a wrong turn, but the watch buzzes reassuringly when you get back on track.

The heart-rate data on the Fenix was accurate when tested against medical-grade sensors. It calculates VO<sub>2</sub>max over

a range of runs, so at first it gave me a flatteringly inaccurate reading, as well as an estimated marathon time of just under three hours, well outside the realms of possibility. But the longer I used the watch, the more accurate it became.

I could access all my data in the Garmin Connect app. It's easy to use and a great time waster if, like me, you love exercise metrics. The watch tracks tonnes of different sports, including new crazes such as swimrun and paddleboarding. But some aren't perfect, like the climbing tracker that powers off halfway up a pitch. On the extreme end, there's a military-grade parachuting function, which unsurprisingly went unused. **9/10**

*Garmin Fenix 5*  
From £479.99, [garmin.com](http://garmin.com)



## SUUNTO SPARTAN SPORT WRIST HR BARO

The Suunto Spartan Sport looks rugged and durable, and its touchscreen means you can swipe around the watch intuitively, with three buttons to help where needed. The watch was simple to use when running, acquired a GPS signal quickly and tracked flawlessly, even on routes with tunnels or dense tree-cover. The touchscreen didn't work well in the rain, but the buttons cover the essentials.

During exercise, the Suunto read my heart rate 5-6bpm higher than our control medical-grade sensor. It gives a VO<sub>2</sub>max reading after each workout, and mine was a little low, consistent with an overestimated heart rate. My sleeping heart rate also read high, but the watch told me I'd spent a quarter of the night dreaming – perhaps I was being chased by a tiger.

The Suunto Movescount app is frustratingly bare-bones, and you need to use the desktop version for most of the advanced functions (mapping routes, planning workouts and examining data). For a quick run after work, it's a hassle. However, Suunto's heat maps are a highlight. They allow you to see where other people are running or cycling in your city, so you can crowdsource some great routes.

You can plot with virtual breadcrumbs and use the 'find back' function to navigate back to your start point – a potential lifesaver in the mountains – and given the right season, the 'max speed' ski feature would be dangerously fun. **7/10**

*Suunto Spartan Sport Wrist HR Baro*  
From £459, [suunto.com](http://suunto.com)



### VERDICT

Suunto's high-quality, fast GPS and user friendliness puts up a good fight against Garmin's excellent map functions and detailed data. The Fenix 5 was slightly more comfortable, which made a difference over several days of constant wear. In terms of heart-rate data, the Garmin was more accurate. Though the

VO<sub>2</sub>max data was out at first, it improves over weeks of use, so don't be too flattered by your initial reading. Suunto's app let the watch down, especially compared to Garmin Connect, which is packed full of detail. For me, the Garmin took the top spot and if you're a dedicated runner, then it's worth the big investment.





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# THROUGH THE WORMHOLE

COULD WE TRAVEL THROUGH  
A BLACK HOLE TO TAKE A SHORTCUT  
INTO ANOTHER GALAXY?

WORDS: **PROF ROBERT MATTHEWS**





Ever since a trip through a wormhole was first portrayed in *2001: A Space Odyssey* 50 years ago, the idea of them has captured the public imagination.

And small wonder: they're the ultimate form of cosmic travel: a way of zipping across galaxies in an instant.

But while wormholes have become a staple of science fiction, among scientists they've been a source of endless frustra-

tion. Not because the idea is ridiculous, but because it isn't. The astonishing fact is that wormholes are a natural consequence of current theories of gravity, and were investigated by Einstein himself over 80 years ago. Ever since, researchers have been trying to find out if such a bizarre theoretical possibility could be a reality.

And now they have made a major breakthrough – one which exploits deep connections between the nature of space and time and the laws of the subatomic

world. The result is a new understanding of exactly what's required to make a real-life wormhole.

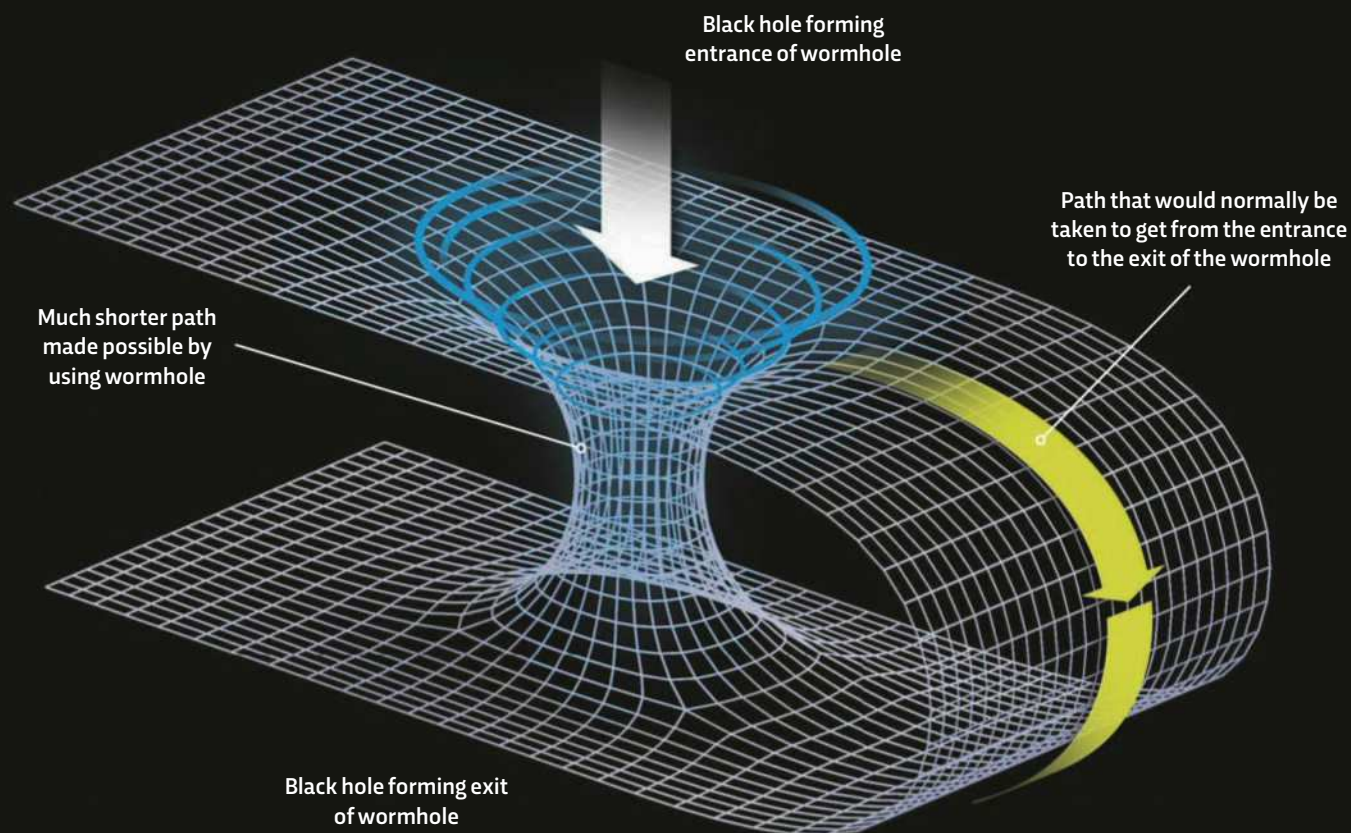
Einstein first investigated the properties of wormholes with his colleague Nathan Rosen in 1935, using his theory of gravity known as General Relativity. They found that what we now call a black hole could be connected to another via a tube-like 'throat'. Now called the Einstein-Rosen bridge, this seemed to open the way to taking shortcuts through space and time,

# WORMHOLE ANATOMY 101

TWO METHODS OF SKIPPING THROUGH SPACE

## 1. THE CLASSIC BUT DEADLY EINSTEIN-ROSEN WORMHOLE

This is the original wormhole version investigated by Einstein. It seems to offer a shortcut through space and time, and thus the possibility of effectively travelling faster than the speed of light. But the Einstein-Rosen bridge inside the wormhole immediately collapses and traps travellers inside, unless it's supported by some strange form of material that generates negative energy.



“They’re the ultimate form of cosmic travel: a way of zipping across galaxies”

entering a black hole in one part of the Universe and emerging from another perhaps millions of light-years away, but without taking millions of years to do so – thus effectively travelling faster than the speed of light.

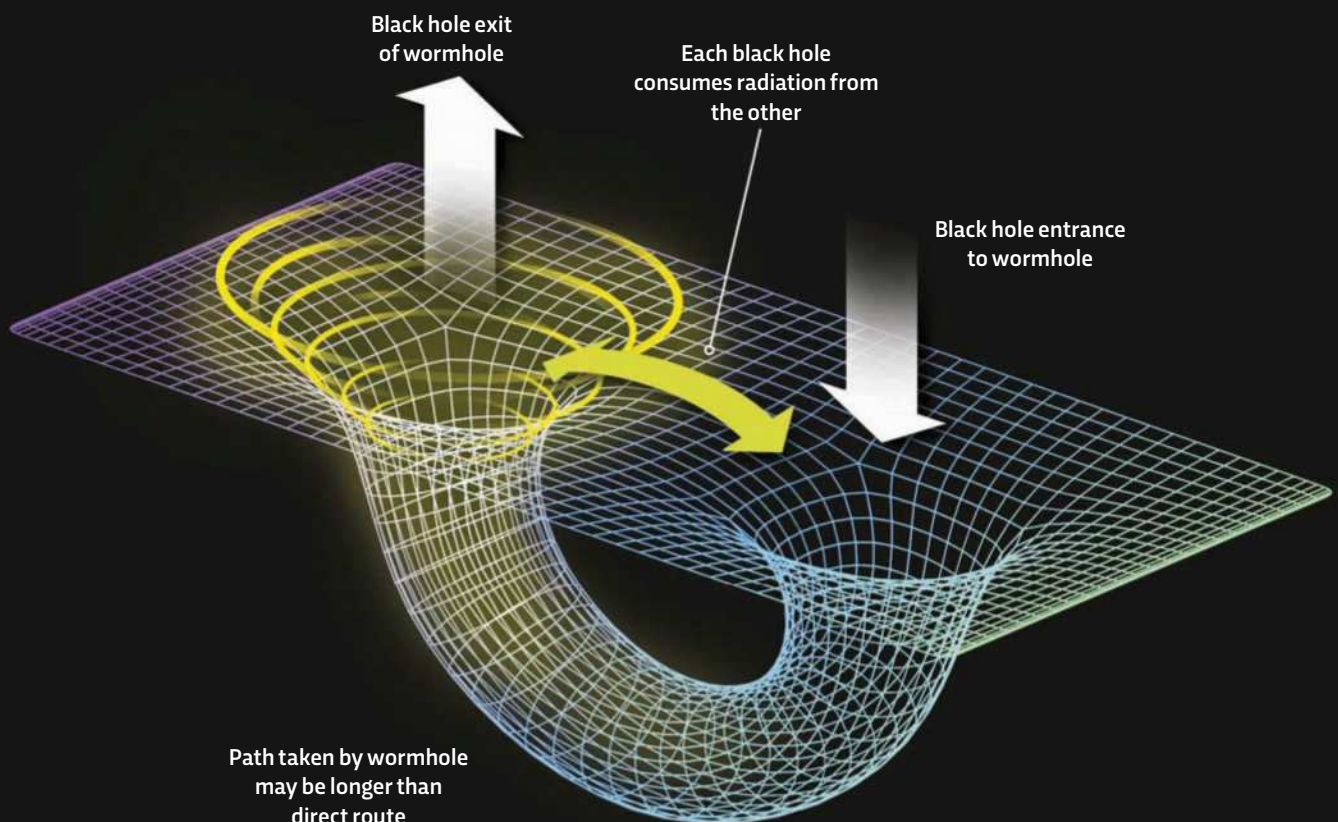
It was a stunning idea, but in the early 1960s it was dealt a severe blow by John Wheeler, the brilliant US physicist who first coined the terms ‘black hole’ and ‘wormhole’. Together with fellow theorist Robert Fuller, he showed that the

Einstein-Rosen bridge would collapse almost as soon as it formed. As Dr Daniel Jafferis, associate professor of physics at Harvard University explains: “We could jump in from opposite sides and meet in the connected interior, but then we would both be doomed.”

Jafferis is one of an elite group of theorists around the world searching for ways to dodge this problem. For years, the most promising idea has been to support the bridge using a type of ‘exotic matter’ with ●

## 2. THE ENTANGLED WORMHOLE

The deadly collapse of the Einstein-Rosen bridge could be prevented if the black holes forming the entrance and exit of the wormhole have a special quantum property called ‘entanglement’. This requires the two black holes to be in direct contact with each other, consuming the radiation that each spews out. But while this keeps the Einstein-Rosen bridge intact, it also means the wormhole might actually be a longer route than simply travelling directly from one black hole to another.





• negative energy. As its name suggests, this is pretty weird stuff – so weird it’s capable of bending the normal rules of gravity. While ordinary matter always generates a gravitational pull, the negative energy produced by this exotic matter generates an antigravitational repulsion. Amazingly, such energy is known to exist. In the 1990s, astronomers discovered that the whole Universe is expanding under the antigravitational effect of so-called ‘dark energy’. There’s just one problem – the exact origins of dark energy are as yet unknown. The same goes for the exotic matter – no one has any idea how to create the stuff, let alone use it keep a wormhole open long enough to fly through.

### THE WORM HAS TURNED

But now the debate over such so-called traversable wormholes has taken a radical new turn. It follows the discovery of a new way of keeping the bridge intact based on a surprising link between wormholes and quantum theory (the laws of the subatomic world). It emerged during attempts to solve a problem that has obsessed some of the greatest theorists of our time, including the late Stephen Hawking: what happens to objects that fall into a black hole?

Everyone knows there’s no escaping a black hole once inside it: the pull of gravity is too strong even for light to evade its clutches. Yet Hawking famously showed that a black hole doesn’t last forever, but eventually explodes in a burst of intense



ABOVE: Dark energy, as visualised here, is responsible for the expansion of the Universe

BELOW: Artist's impression of the event horizon – the point of no return – of the black hole at the centre of our Galaxy



“The good news is that traversable wormholes really can exist”

radiation, leaving no trace of whatever fell into it. The trouble is, this contradicts one of the key principles of quantum theory, which states that information can never be destroyed. Black holes, however, seem quite capable of utterly destroying information about what they’ve consumed. This is the notorious ‘black hole information paradox’, and it hints at a big gap in our understanding of how the Universe works.

For decades, Hawking and many others tried to resolve the paradox without success. But now there’s growing excitement that the answer has been found. And it lies in the ability of wormholes to provide a way out of black holes. Put simply, theorists think the supposedly inescapable boundary of a black hole – the so-called event horizon – is riddled with

Black holes will destroy anything that is drawn into them, like this star. Yet wormholes could provide a way out

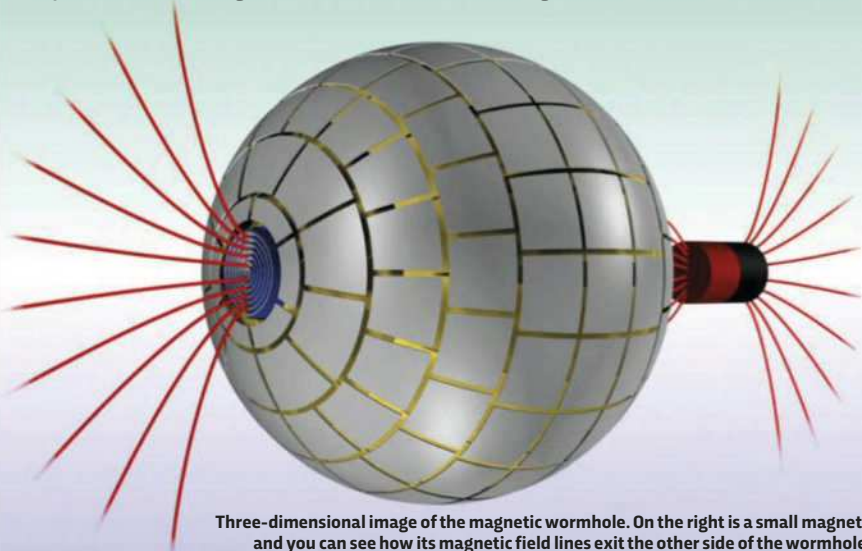


## CREATING A REAL-LIFE WORMHOLE IN THE LAB

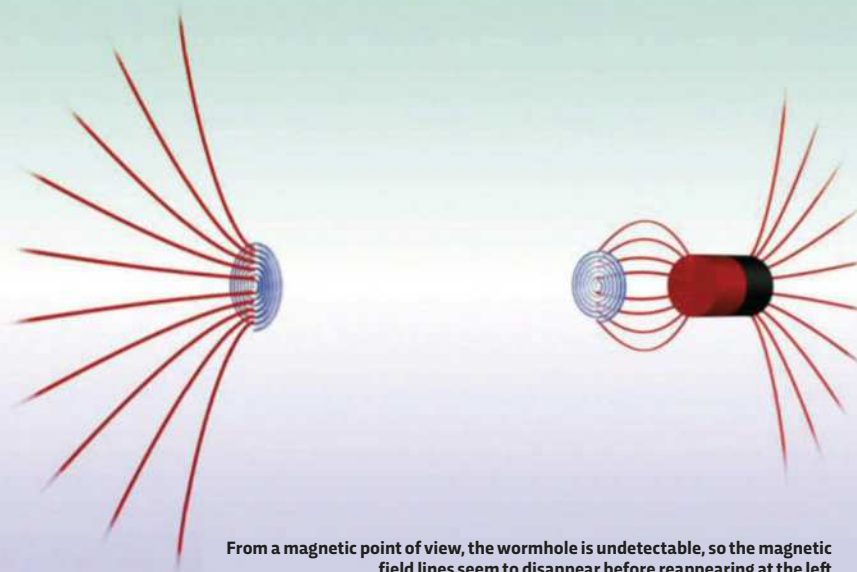
While theorists wrestle with the possibility of cosmic wormholes, researchers in Spain have succeeded in making one in the lab – by swapping gravity for magnetism. The result is a wormhole that takes magnetic fields in at one place and then allows them to magically reappear somewhere else.

Alvaro Sanchez and his colleagues at the Autonomous University of Barcelona pulled off this feat by creating a sphere made from special conducting materials that respond to magnetic fields in different ways. Carefully arranged in layers, these materials have the effect of modifying the way empty space transmits magnetic fields.

The result is a device that acts as a wormhole where a magnetic field enters on one side of the sphere, completely disappears once inside, and then appears again on the other. This is no mere party trick, either. The wormhole device allows magnetic fields to travel from place to place without affecting anything on the way. According to the team, it has many applications – such as in MRI scanners in hospital. Instead of having to lie claustrophobically close to the magnetic coils needed to create MRI images, patients could have the magnetic field sent to them from a separate room via the magic of the wormhole.



Three-dimensional image of the magnetic wormhole. On the right is a small magnet, and you can see how its magnetic field lines exit the other side of the wormhole



From a magnetic point of view, the wormhole is undetectable, so the magnetic field lines seem to disappear before reappearing at the left

tiny wormholes that allow information to seep out, along with the radiation which Hawking showed destroys black holes. This, in turn, has led to new insights into the nature of wormholes, and whether they can be traversed.

Until now, the only known way to traverse a wormhole was to stop the Einstein-Rosen bridge collapsing using the negative energy of exotic matter. “Quantum effects allow some negative energy,” explains Jafferis. “But it was long suspected that what is required for a traversable wormhole is physically impossible.”

Now, Jafferis and his colleagues Dr Ping Gao and Dr Aron Wall think they’ve discovered another source. “What we found is that a direct interaction between the [black holes at the] two ends of a non-traversable wormhole can lead to negative energy,” says Jafferis. The resulting antigravitational effect then stops the Einstein-Rosen bridge from collapsing, therefore making the wormhole traversable.

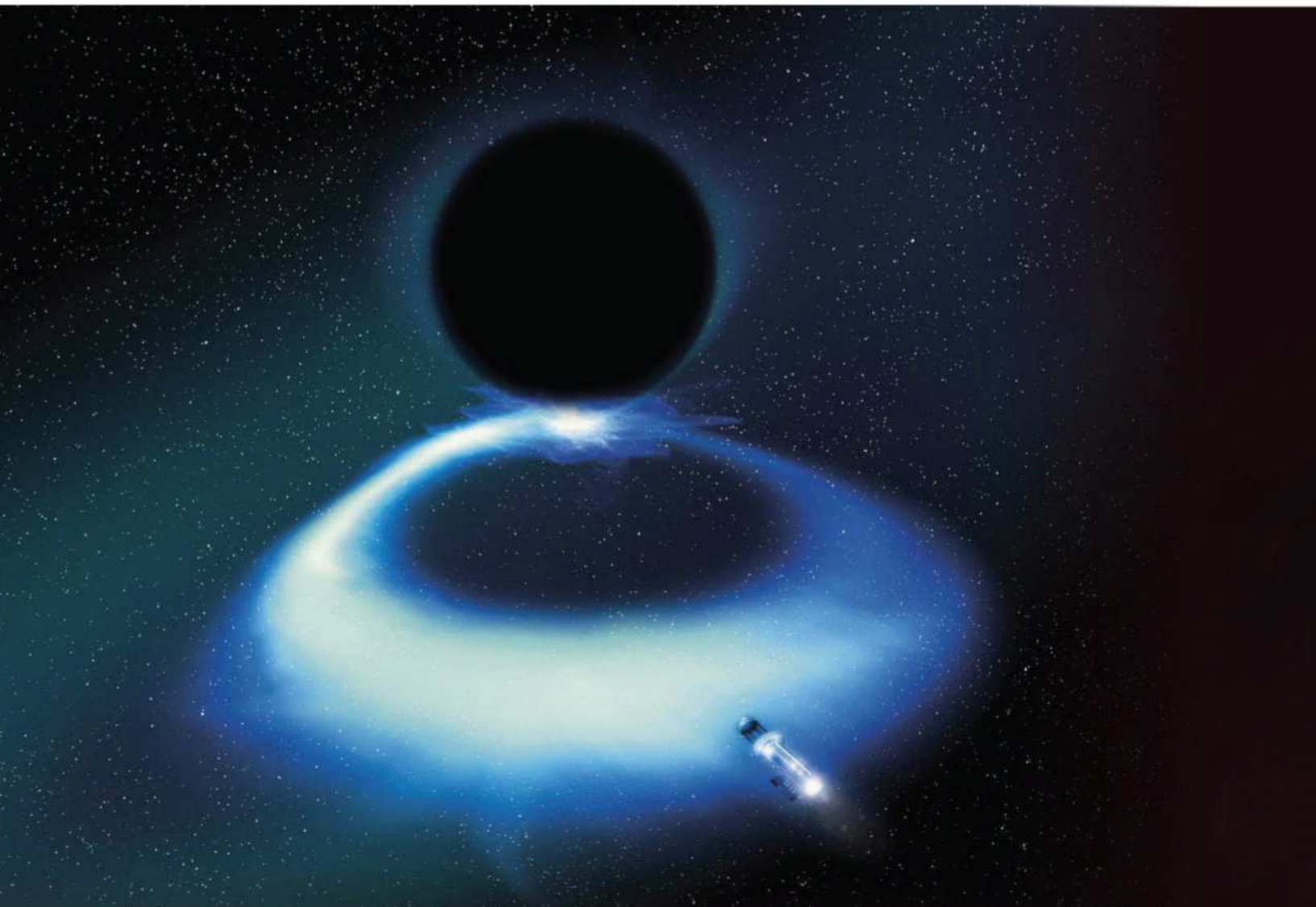
When Jafferis and his colleagues say “direct interaction”, they mean that the two black holes forming the mouths of the wormhole are affecting each other across real, ordinary space. “Binary black hole systems consuming each other’s Hawking radiation is a good example,” says Jafferis. “The consuming of the radiation is the direct connection.”

### IN A TANGLE

So, the good news is that traversable wormholes really can exist. Better still, according to Jafferis there’s no problem sending a human through one of them, at least in principle. But, perhaps unsurprisingly, there are some major problems to overcome. First, the black holes can’t just be the standard type formed from the collapsed remnants of huge stars; they have to be ‘maximally entangled’. This refers to a strange quantum connection that can exist between two objects, so that anything done to one affects the other instantly – no matter how far apart they are.

Like negative energy, the bizarre phenomenon of quantum entanglement really exists. It was first detected in lab experiments nearly 40 years ago, and it’s now being investigated by companies like Google for creating ultra-fast quantum computers. Yet while subatomic particles can be entangled relatively easily in the lab, no one has any idea how to do the same with black holes. “We can’t even make unentangled black holes, let ▶





• alone precisely quantum entangled ones,” explains Jafferis.

Yet direct interaction between two black holes comes with a catch: it forbids any amazing time travel trickery. But could it still allow faster-than-light travel? That’s a tricky question, says Jafferis. Gravity, space and time are all intimately linked, and that messes with the very notion of

speed. According to Jafferis, calculations based on the wormhole types studied so far suggest that using them would actually be slower than simply travelling directly through space. He admits, though, that the details have yet to be fully worked out. So, it seems that science fact is still running a little behind science fiction. The laws of nature seem to insist that wormholes can either perform amazing feats but collapse in an instant, or be traversable but useless.

Yet time and again, nature has sprung big surprises on theorists. The mere possibility of black holes was disputed for decades, and Einstein himself refused to believe in quantum entanglement. Could it be that somewhere in the Universe lie natural wormholes performing their miracles?

#### SCIENCE OR SCI-FI?

The possibility of observing a real-life wormhole is now the focus of research by theorists using a mix of mathematics and computer models. The challenge is spotting the difference between normal

ABOVE: In future, could we travel to black holes to capture samples of Hawking radiation to help improve our understanding of wormholes?

RIGHT: Scientists can study the shadow that a black hole casts on its hot, bright accretion disc. Certain shapes of shadow may reveal that the black hole is, in fact, a wormhole

“The mere possibility of black holes was disputed for decades, and Einstein himself refused to believe in quantum entanglement”

black holes and those that are the portals of wormholes. According to Rajibul Shaikh, a gravity theorist at the Tata Institute of Fundamental Research in Mumbai, India, the answer may lie in subtle differences in the way they affect their surroundings – and in particular the behaviour of light. “As predicted by Einstein’s General Relativity, photons undergo bending in a gravitational field,” he explains.


The intense gravity of black holes creates incredibly hot, bright accretion discs around them, formed of matter spiralling down to its doom. The otherwise invisible hosts of these discs then reveal their presence as a pitch-black shadow cast on them. It’s the shape of this shadow that could reveal when a black hole is actually something even more bizarre. According to Shaikh, the telltale signs of a wormhole come from the gravitational effect of its throat on the resulting shadow.

“What I found is that the shape of the shadow of a slowly rotating wormhole would be very similar to the almost perfectly disc-like shadow cast by a slowly rotating black hole,” he explains. “But

a faster spinning wormhole would cast a shadow which is more distorted than that of a black hole with the same spin.”

He stresses that research is still in progress, and the results so far are based on specific types of black holes and wormholes. “There’s no guarantee the type of rotating wormholes I considered are the most common.”

But Shaikh points out that astronomers already have the means to detect the effects predicted to exist around wormholes. Known as the Event Horizon Telescope (EHT), it consists of a global network of radio antennas able to make studies of black holes and wormholes. “And it has already started taking data,” says Shaikh.

It could just be that, half a century after it made its debut on movie screens, the space-time wormhole is about to become more than just science fiction. 

**Robert Matthews** is visiting professor in science at Aston University, Birmingham.

#### DISCOVER MORE



Listen to Prof Stephen Hawking delivering his BBC Reith Lecture on black holes at [bit.ly/reith\\_hawking](https://bit.ly/reith_hawking)





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# THE SCIENCE OF PAY TRANSPARENCY

In the UK, women are paid around 10 per cent less than men, on average. One solution might be total pay transparency. Can it fix the problem and are we ready to talk about how much we earn?

WORDS: MOYA SARNER





# “In a real workplace, the case for transparency grows more opaque”

**T**here is a revolution stirring. It's taking shape in offices, around dinner tables and in newspaper headlines around the UK: people are talking about how much they earn. Keeping a polite silence around money is such a long-standing cliché of what it means to be British that for some, simply having these conversations cuts to the core of how we think of ourselves and our society.

On 5 March this year, almost 250 staff of the BBC – British by name, but no longer it seems by nature, in this respect at least – signed an open letter to the director general Tony Hall, demanding “full pay transparency”. This followed a review of the broadcaster's pay last summer which found that only one-third of the 96 best-paid employees were women, none of whom were in the top seven. Then in April, large firms and public bodies were required to publish figures comparing men and women's average pay, revealing that 78 per cent of them pay men more.

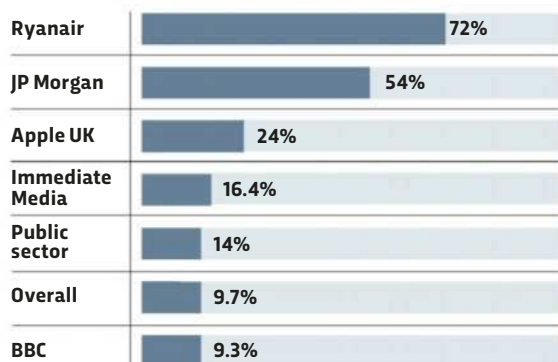
The BBC staff who signed the letter demanding pay transparency argue that it constitutes the “fastest, cheapest and fairest way to begin to tackle unequal pay,” and that it is the most effective way to uncover pay discrimination due to race, gender, age or class. The CEOs of those companies that have adopted the policy – so far low in number but high

in enthusiasm – believe it is an improvement on the way we have always done things. But what is the evidence? Given we have laboured (quite literally) under pay secrecy for so long, what would such a dramatic shift do to our minds?

Despite its longevity, there have been some experiments suggesting that pay secrecy may be the worst possible policy we could have in the workplace, for both employers and employees. In one study by Elena Belogolovsky at Cornell University and Peter Bamberger at Tel Aviv University, participants were divided into groups of four and asked to perform a task on a computer. After each round, one set of groups saw a bar chart on the screen showing only the amount they as an individual would be paid for their performance, and they were forbidden from discussing their remuneration with others in their group over the monitored email system – mimicking pay secrecy conditions. Those in the second set of groups, working under pay transparency conditions, also saw a second bar chart showing their reward relative to other participants, and were told their email communications had no restrictions. After three rounds, the researchers found that those in

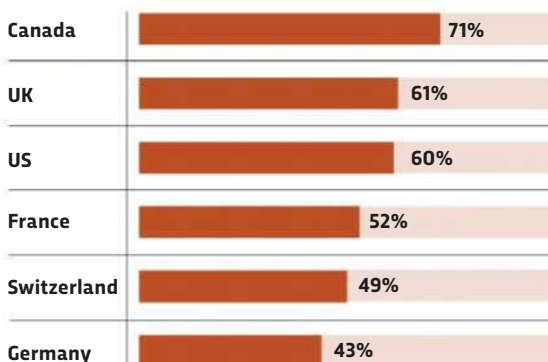
## A CLEAR PROBLEM...

### GENDER PAY GAP IN SELECTED UK COMPANIES



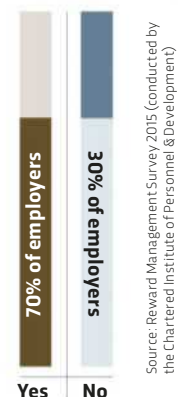
Source: Government Equalities Office, 2018

### HOW TRANSPARENT ARE WE NOW?



Source: Global Salary Transparency Survey (conducted by Glassdoor)

### WILL GREATER TRANSPARENCY REDUCE THE GAP?



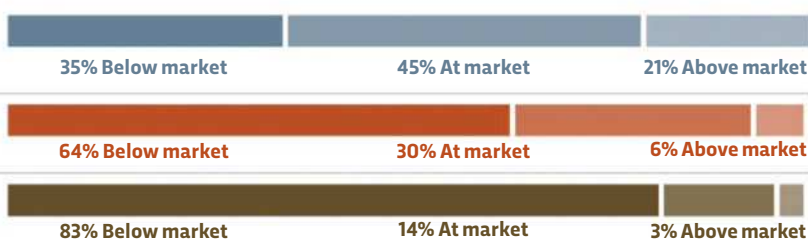
### ARE OUR PERCEPTIONS OF PAY 'FAIRNESS' ACCURATE?

35% of people who are paid **above the market** average for their job believe they are paid less than the market average. Women in this bracket are 18% more likely than men to believe they are underpaid.

64% of people who are paid the **market average** for their job believe they are paid less than the market average.

3% of people who are paid **below the market average** for their job believe they are paid above the market average.

Source: Harvard Business Review





ABOVE: In the UK there's a 9.8 per cent median pay gap between men and women

the pay secrecy group performed worse and would be less willing to come back. Further studies by Belogolovsky and Bamberger found that employees collaborate more effectively under transparent conditions, as they are better at assessing the best colleague to approach for advice, based on knowledge of their salaries. Belogolovsky says: "In pay-for-performance systems, pay secrecy has a negative impact on individual task performance and retention because it weakens the perception that an increase in performance will be followed by increase in pay."

The evidence seems clear: secrecy obstructs productivity. But what happens in a real workplace? Here, the case for transparency grows more opaque.

#### POTENTIAL DRAWBACKS

Researchers Jordi Blanes i Vidal and Mareike Nossol at the London School of Economics sought to answer this question using data from a German wholesale and retail firm which began informing its employees how they were paid, and how productive they were, relative to their colleagues. As a result, productivity improved by 6.8 per cent.

But when David Card, professor of economics at the University of California, performed an experiment on other staff at his university, the results were not so positive. Randomly chosen

staff members were sent a link to a website set up by a local newspaper which listed the salary of all state employees, including those working for UC – with no information about productivity levels – and then surveyed them about their pay, job satisfaction and job search intentions.

Unsurprisingly, he found that workers who were paid below the median in their department felt less satisfied in their job and intended to look for another. But those who were paid above the median did not report any significant improvement in job satisfaction or shifts in their intention to move. The negative impact of pay transparency among those who earned less was not off-set by the positive impact among those who earn more, and that means, according to Card, "employers have an incentive to maintain pay secrecy." Little wonder it has been the norm for so long.

Joel Gascoigne, CEO of the social media management platform Buffer, believes the incentives for pay transparency are far greater. He is committed to what he calls "radical transparency", publishing not just the salaries of all his employees but also revenue data and details of diversity of his employees. "When we moved to pay transparency within the company, most of our concerns were around the uncertainties of what might happen," he explains. "It is still a very uncommon practice, so ●





ABOVE: At Buffer, which develops and sells social media tools, a policy of complete pay transparency has been introduced

ABOVE RIGHT: Would you be happy with your payslip being open to public scrutiny?

● there were almost no resources to look at or people to advise us. But we found that all of these concerns were unfounded and hypothetical, and that the massive benefits far outweighed challenges – there was an immediate growth in the level of trust among team members, and the overall sentiment was very positive. Knowing how much everyone else was making, knowing the formula used and seeing it was fair was comforting for people.”

When the salaries were published online for the general public, it was not quite so straightforward, he explains. “That was a little more psychologically challenging, and we had more conversations and discussions about it. There were some fears that people had around what may happen once their salary is public for the world to see and know. Today at Buffer, internal pay transparency is incredibly important and something we don’t deviate from. But when it comes to public transparency, we now allow team members to opt out, for example, if there are personal safety concerns.”

It’s not easy, he adds, but it’s worth it: “Pay

transparency, like many other forms of transparency, requires extra work. It takes time to create a clear and fair compensation system, and it requires maintenance and expansion over time (we’ve had several iterations of our formula). Arguably the company could move faster on certain initiatives, and perhaps even have higher growth, at least in the short term, if we didn’t hold ourselves to the level of transparency we do. However, when you take a long-term mindset, it is a very easy decision to put in the effort. It breeds trust by removing any ability to use control of data to hold power,

and by opening up all the information for anyone to question. It enables innovation by ensuring that the whole team has all the information at their disposal to make key decisions – usually only top level executives have all the cards. It leads to fairness and greater justice by inviting any team member and the greater public to question or call us out on our compensation system.”

After Gascoigne took the decision to go transparent, he reported a huge increase in the number and quality of applicants to Buffer.

This is key, says Sir Cary Cooper, professor of organisational psychology and health at Manchester Business School: simply telling people what they are paid in relation to their colleagues is not enough. It has to lead to something more. Asked if pay transparency is, psychologically speaking, a good thing, he heaves a big sigh.

“I think it would be a good thing if the transparency also led to openness,” he says. “If the organisation had managers who were open to people coming to them to do discuss, openly, their own value and worth and fairness. If they have that kind of culture, I think it could work. If they don’t, then I think it might cause conflict and problems.”

For Belogolovsky, too, transparency in itself can only be part of the solution: “I believe that the real issue is not whether pay should be transparent or not but rather whether the compensation system is



**“At a psychological level, there is always a consequence of sharing information that is irrational as well as rational”**

equitable, well managed and well communicated. Neither a transparent pay policy where employees can compare salaries nor pay secrecy is a solution for an unfair system. In practice, however, at least some degree of pay transparency is necessary in order to convince employees that the organisation's compensation system is equitable and fair."

### EMOTIONAL IMPACT

The less fashionable, arguably more realistic approach to this question is to recognise the true impact that revealing this kind of information might have. Robyn Vesey from Tavistock Consulting says we need to think about how an organisation's systems and structures can affect its employees psychologically, and the impact our unconscious motivations and processes have on our work and our colleagues. The question of who gets paid what in relation to whom brings up extremely complex feelings, she says: "It's about numbers and it's about more than numbers. Who deserves what is such a key anxiety of our age, whether you're talking about claiming benefits or pay in high level jobs."

She suggests one benefit of organisations keeping salaries secret is that it helps to manage anxieties that accompany feelings around recognition. "Pay is very charged, in that it's linked to these sorts of emotions. There are ways in which the current system works to keep in place some aspects of competition and of rivalry across all employees, to contain some of the strong feelings people might have about their remuneration," she says.

This might sound like a counter-intuitive approach – but that is why it is so important to reflect on it, Vesey explains. "In our age, we don't often consider the flipside of having more information. At a psychological level, there is always a consequence of sharing information that is irrational as well as rational, and that balances the assumption that the impact is always positive."

That is why hailing transparency as some kind of cure-all must be overly simplistic. Because although debate around transparency and the gender pay gap might appear to be economic, it is also profoundly psychological; it is about being and feeling valued.

"This is the thing about pay transparency," Cooper tells me, "It's about what it says to you as the individual employee about whether they value you or not. It's about more than the money." If we think of the concept of value as the intersection of psychology and finance, it is clear that while transparency might shine a light on the problem, sharing information will not solve it: employers need to put their money where their mind is. 🗨️

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**Moya Sarnier** is a freelance writer and editor. She tweets from @Moyasarnier

## HOW TO GET A PAY RISE

Advice from organisational psychologist Liane Davey, author of *You First: Inspire Your Team To Grow Up, Get Along, And Get Stuff Done*

### 1 CHOOSE YOUR MOMENT

"Tie the timing of your request for a rise to positive results. If you have a notable success in the middle of the year, start the discussion soon afterwards. Even if the pay cycle means the rise cannot happen for some time, you will have seeded the conversation at a moment when your manager is feeling positively inclined towards you."



### 2 KNOW YOUR WORTH

"Before making your request, write down a list of your accomplishments, and ask a trusted confidant what you bring to the team – particularly what is unique about your contribution – to ensure you get a comprehensive list. Be prepared to talk about the impact you have, rather than effort alone, as this is what makes your case for a rise compelling."



### 3 PLAY IT COOL

"In difficult conversations, your tone and body language are especially important. Go in calmly and projecting that you believe you are adding value. Don't under-do it by dropping eye contact or making yourself smaller. But don't over-do it by raising your chin too high or making statements or ultimatums you don't intend to follow through – that will destroy your credibility."



### 4 ASK FOR CLARITY

"If you are unsuccessful, first find out why your request was denied. Do not let your manager away with a superficial answer such as 'we don't have the budget' – there is *always* budget, so ask what else took priority. Next, ask what specific actions you can take that will make you more likely to be given a pay rise in future."



### 5 BE FLEXIBLE

"Remember that pay is only one way your company can demonstrate your value. Some companies have little room for pay rises, but more room to negotiate on annual leave, flexible hours or working from home. If your efforts to get a rise are unsuccessful, do not give up without first searching for alternative sources of value."





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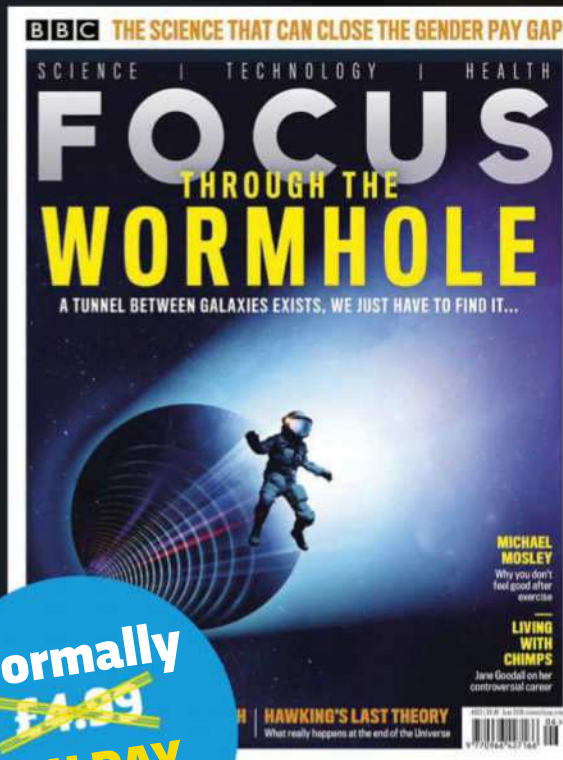
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# “WHEREVER I GO, I SEE LITTLE BITS OF NATURE, LITTLE BITS OF ANIMAL BEHAVIOUR. AND NOBODY ELSE IS WATCHING”

In 1960, **Jane Goodall** travelled to Africa with the aim of integrating herself into a community of wild chimps. Now nearly 60 years on, her observations have transformed the way we see our primate cousins. She met up with **Sarah Begum** to look back over her distinguished career

## How did your journey begin?

I was born loving animals. I had a supportive mother – she found books for me to read about animals, thinking that I’d learn to read more quickly. I read *Tarzan* when I was 10, and that’s when my dream began: to go to Africa, live with wild animals and write books about them. I never thought about being a scientist, because there weren’t women scientists doing those things in those days. It was wartime, we had little money and my father was off fighting, so Africa was a long way away.

I hadn’t been to college – I couldn’t afford it. We had just enough money for a secretarial course, so I got a job in London as a secretary. When I was 23, I was invited to visit a schoolfriend in Kenya, so I gave that job up, moved back home and worked as a waitress in

Bournemouth to save money for the sea voyage. It was in Kenya that I met the palaeoanthropologist Dr Louis Leakey. Somebody suggested I see him if I was interested in animals. Guess what? He needed a secretary. So that boring old course led me to a job with him. He was interested in knowing the similarities between early humans and chimps, and he eventually decided that I was the person he’d been looking for, for 10 years, to go to Tanzania to study chimps.

## What do you think has been your greatest discovery relating to chimpanzees?

It’s hard to say. I mean, the discovery that led to press coverage in *National Geographic* magazine was chimpanzees using and making tools, at the Gombe National Park in Tanzania. The chimps used grass stems to fish for termites, and

leafy twigs where they removed the leaves to turn it into a tool. This was in 1960, and at that time, it was thought that only humans used and made tools.

## What’s your favourite memory of your time spent with chimpanzees?

One really special memory was the first chimp to lose his fear – David Greybeard. He showed me tool use and finally allowed me to follow him in the Gombe forest. I was crawling after him through thick bushes and brambles, and there he was looking back as though he was waiting for me. There was a ripe, red palm nut on the ground. I held him and held the nut out on my hand. He reached, took the nut, dropped it because he didn’t want it, but he gently squeezed my hand, which is how chimps reassure each other. In that moment, I knew that he ●





● knew my gesture was good. That was communication at a pre-human level.

### What was your most challenging moment?

It was getting the chimps not to run away. When I started my research, I wasn't allowed to be alone in the field – the British government wouldn't allow it – so I arrived on the shore of the Gombe with my mum and a cook. But the chimps kept running away: they'd never seen a white ape before! I'd get back from my observations depressed, and Mum would always point out what I was discovering: how they move around alone or in little groups, sometimes all joined together if they see a new, ripe fruit; how they make beds at night in the trees by bending over the branches; how they make tools. She boosted my morale. To get the chimps used to me, I wore the same coloured clothes every day. I didn't try to get too close too quickly. And I was patient. It took over a year for them to accept me.

### You became close to the chimpanzees you studied. Is this something you felt was necessary to understand the animals?

I think you couldn't possibly understand them if you didn't know them, didn't know their personalities. And with them not minding me being there, watching them, that was the key. Yes, it was necessary. David Greybeard helped me in a way. Usually, when I arrived, the other chimps would be ready to run. But if David was there, they'd just look from him to me and I suppose they thought, "well, she's not too frightening after all".

### Is there anything that, with hindsight, you would have done differently?

I made mistakes, but I learned from them. Today, we wouldn't feed the chimps bananas – we try not to interact with them directly because diseases can transfer. Back then, nobody had done this before. I think I was rather like an anthropologist, meeting an uncontacted tribe, giving them gifts. The bananas got the chimps close, and if the chimps hadn't come close, *National Geographic* wouldn't have sent a photographer, the behaviour wouldn't have been filmed, and the study would have ended. It would be a mistake today, but I don't believe it was a mistake then.

### Do you think your time with chimpanzees has shaped how you view humans, too?

In airports, I'm watching the different

ways mothers cope with fractious children, the way young men and women behave when they're about to separate or when they reunite. I watch people becoming angry and shouting because their plane is delayed, even though the people they are shouting at can't help it. I'm just watching how people behave in different situations as though they're chimps.

### Do you think that we're still evolving?

I don't think we're evolving. I think technology is evolving and changing people. It's not the kind of evolution that has brought us to be what we've become. Little kids of three are given video games; children on a bus text each other, rather than speak. They're not interacting with nature at all. This is a tragedy because there's proof that children need contact with nature for good psychological development.

### What if this continues?

I don't know, I don't want to think. My Roots & Shoots programme is trying to get children back out into nature, or bringing nature into the classrooms, encouraging curiosity and hands-on exploration rather than doing everything virtually. Wherever I go, I see little bits of nature, little bits of animal behaviour. And nobody else is watching because they spend nearly all their day on some kind of technology – they're missing out on an awful lot of enjoyment and fun.

### As a woman in science, did you encounter any barriers?

## LIFE IN THE FIELD

**1934** – Born Valerie Jane Morris-Goodall in London.

**1957** – Travels to Kenya to visit a school friend, meeting palaeoanthropologist Dr Louis Leakey while she's there. Unbeknown to her, Leakey is looking for someone to study chimps in their natural habitat.

**1960** – Arrives with her mother at Gombe Stream Chimpanzee Reserve (now Gombe National Park) in what is now Tanzania, where she discovers that chimpanzees make and use tools. In the same year, she also discovers that chimps are omnivorous, not vegetarian as previously thought.

**1961** – Begins her PhD at Cambridge University, becoming one of the few people to be admitted without an undergraduate degree.

**1963** – Appears on the front cover of *National Geographic*, bringing her story into the public spotlight.

**1971** – Publishes *In The Shadow Of Man*, a now-classic account of her early field research in Gombe.

**1974-1978** – Witnesses the 'Four-Year War', a violent conflict between two chimp communities in Gombe, which reveals that chimp societies – much like human ones – have a dark side.

**1977** – Founds the Jane Goodall Institute to support the research in Gombe and help protect chimpanzees and their habitats.

**1991** – Founds the Roots & Shoots youth programme, now active in nearly 100 countries around the world, with the aim of inspiring the next generation of conservationists.

**2002** – Named a United Nations Messenger of Peace for her work in raising awareness of conservation and environmental issues.



In 1965, National Geographic produced its first film, *Miss Goodall And The Wild Chimpanzees*, which followed Jane and her research

I did, but I don't think it had anything to do with being a woman. I went to Cambridge to do my PhD in 1961, but I had no undergraduate degree, so my professors were a bit nervous. They told me I had done everything wrong in my field research: I shouldn't have given the chimps names, they should have had numbers. I couldn't talk about their personalities, their minds or their emotions because those things were unique to us. In my first scientific paper, every time I put 'he' or 'she', the editor crossed it out and put 'its' and 'which'. I was furious, so I put them back in. You can't deny that chimps have sexual differences. I had a wonderful supervisor, Robert Hinde, who was very critical, but then he came to Gombe and he could no longer dispute what I said.

#### **Do you think young female researchers today face barriers?**

Women can do many things now that were frowned upon back then. When I was 16, 17, 18, my friends at school were planning to become a secretary, air hostess, nurse or missionary's wife. I was lucky because Louis Leakey felt that women were better in the field. He believed we were more observant – that, evolutionarily speaking, women need to be good mothers, and to be a good mother, you need to be patient. He was right, but he also wanted somebody who hadn't been to university, someone whose mind was free from the restrictive training at the time. That was why he chose me. Today, there are hundreds of doors open to women. It may be more of a struggle for them to go through than for a man, but doors are open.

#### **What would be your advice to women who want to follow in your footsteps?**

Work hard, take advantage of opportunity, and never give up. You've got to really want to do this because there's a lot of competition and it's hard to get money for research, so you'd better really be passionate about it.

#### **Having travelled the world for so many years, what changes have you seen?**

Humans are destroying the planet very, very fast. We're cutting down the rainforests, covering huge areas of land with development and concrete. We're penning animals into factory farms with unspeakable cruelty, destroying environments to grow grains to feed



Taking field notes on chimpanzees in 1987

***“Many young people have told me that they have lost hope because we’ve compromised their future and there’s nothing they can do about it”***

those animals. We're using masses of fossil fuels to transport the grains to the animals, who get slaughtered into meat at the table. It's adding to the CO<sub>2</sub> released into the atmosphere by our fossil fuels. The sea is increasingly polluted. The ice is melting and the sea levels are rising. We're using up nature's resources as though they're unlimited, and they're not. Many young people have told me that they have lost hope because we've compromised their future and there's nothing they can do about it. We *have* compromised their future, but I think

there's a window of time to try and heal some of those scars.

#### **Do you feel hopeful for the future?**

I think the human brain has the power to come up with technological solutions to these problems. Nature is also resilient: I think that places that we've destroyed can once again be restored, and animals on the brink of extinction can be given another chance. Another hope is social media, which is effective in uniting people from all around the world to protest about plastic pollution and similar issues. I think there's an indomitable human spirit, which taps into what seems impossible and inspires us not to give up.

#### **Where should we focus our efforts?**

Everyone should realise that every single day we live, we make some impact. If it was just you picking up plastic, just you turning off the lights, just you walking instead of driving, then it wouldn't make much of a difference. But if it's millions and then billions of people making ethical choices – what they buy, what they wear, what they eat, how they behave, how they treat animals – then the world would start moving towards a better way. We should think of the consequences of the little choices we make each day, and how that will affect future generations. 🌱

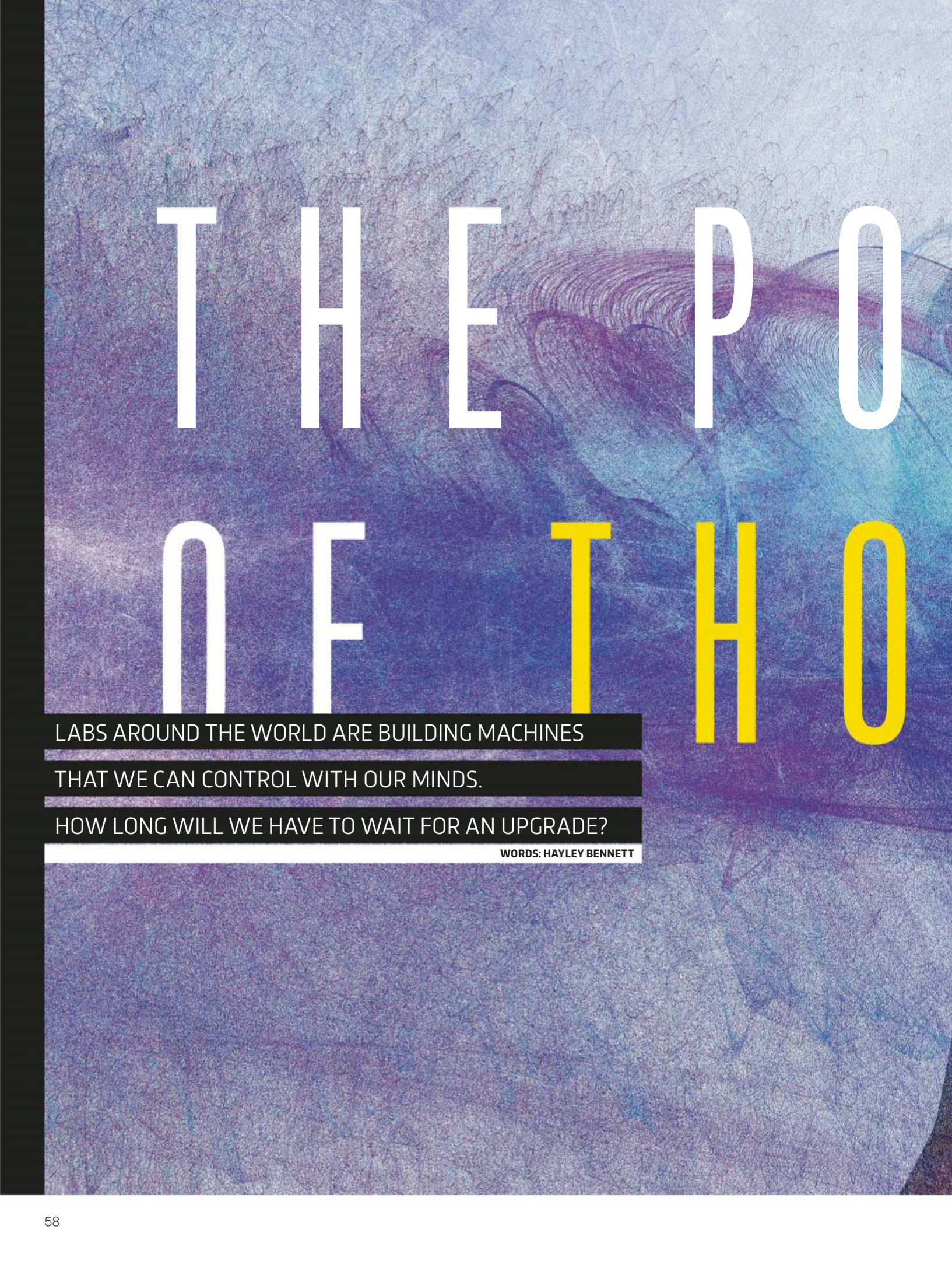
Sarah Begum is a journalist and filmmaker.

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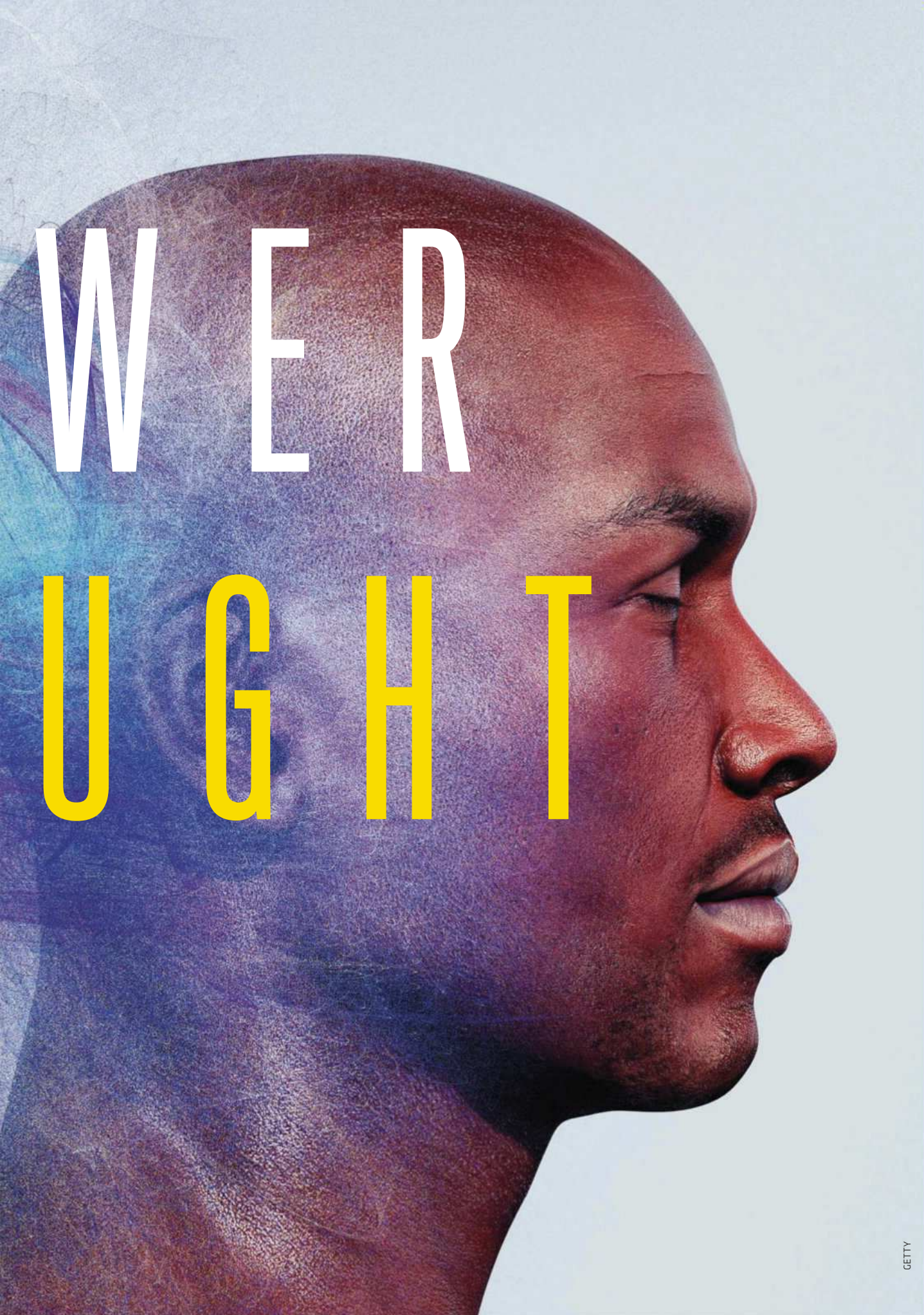
LABS AROUND THE WORLD ARE BUILDING MACHINES

THAT WE CAN CONTROL WITH OUR MINDS.

HOW LONG WILL WE HAVE TO WAIT FOR AN UPGRADE?

WORDS: HAYLEY BENNETT





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LEFT: Back in 2009, the Honda Research Institute demonstrated a helmet that allowed a user to control an ASIMO robot by thought alone. Yes, it looked a little clunky, but it represented a ginormous leap forwards in technology

RIGHT: This exoskeleton was modified to include a brain-machine interface that allowed Juliano Pinto, a young paraplegic, to make the symbolic first kick at the 2014 World Cup

**Y**ou get back from work, crash out on the sofa and pick a track from your favourite playlist. Without moving from that spot you start heating up the oven to cook dinner before beginning a conversation with your friend who lives on the other side of town. You do all this without ever saying a word or pressing a single button. How did anyone get anything done before brain interfaces?

The idea that we could run our lives from inside our heads is, obviously, a fantasy, but there are those who are attempting to make it a reality. In 2017, SpaceX and Tesla billionaire Elon Musk announced a new venture, Neuralink. Its aim: to build a high-bandwidth, implantable brain-computer interface that will put us permanently online and allow us to communicate wirelessly with anything that has a computer chip. The device could, theoretically, allow us to have thought conversations with our friends, share memories as if they were smartphone videos and 'know' anything we wanted by simply calling it down from the cloud.

Meanwhile, earlier this year, the US Defense Advanced Research Projects Agency (DARPA), announced plans to develop next-gen brain-computer interfaces, with the aim of enhancing the abilities of military personnel. A recently released document suggested a possible experiment for testing these devices: "a human subject controlling multiple drones in a virtual

BELOW: Neurable's brain-computer interface replaces the headstrap of a VR headset with electrodes that read brain activity, so users can control VR games with their mind

reality setup, while receiving sensory feedback to portray the status of each drone." In other words, we might one day see soldiers controlling drones with their minds.

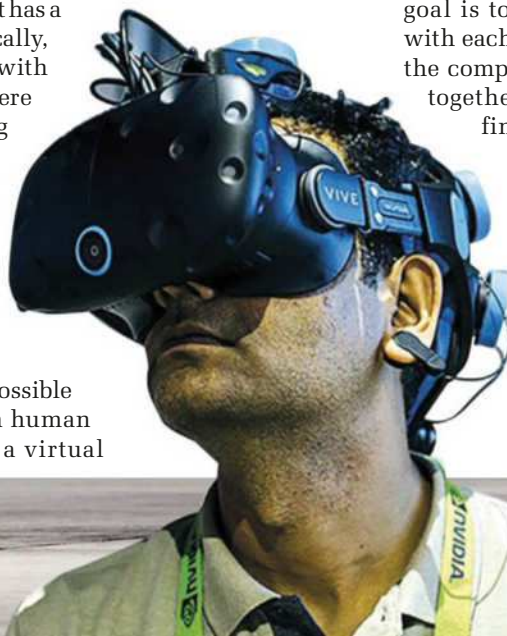
It sounds impressive, but is it possible? Primitive versions of brain-machine interfaces have already been used to help paralysed people move prosthetic limbs, but could we really see this technology making the leap to everyday use?

#### GROUP THINKING

A brain-computer interface is a device that's able to read the electrical impulses coming from the brain's nerve cells (neurons) using electrodes and ideally also write to the brain, delivering information to the user by stimulating groups of neurons. Neuralink's ultimate goal is to build an interface that interacts directly with each of the 86 billion neurons in our brains, and the company is apparently in the process of putting together a crack science team for its project. The finer details of exactly how Neuralink plans to do this remain under wraps, however.

"I'm still looking for more information on this," says Dr Davide Valeriani, who studies brain-computer interfaces at the University of Essex. "Musk has announced these initiatives and then for a while hasn't said anything else."

Valeriani works with the kind of brain-computer interfaces that you might be more familiar with – electroencephalography (EEG) caps, those



ugly skullcaps with all the sensors and wires attached to them. “You can imagine this as a system you can put in a backpack, with electrodes integrated into something we wear already, a hat or hairnet or whatever,” says Valeriani. All it takes to get this system working for a particular user is half an hour or so of training, not for the human but for the machine, which has to learn which patterns in the person’s brain are associated with certain thoughts.

Valeriani uses these EEG setups for group decision-making tasks. In one experiment from a 2017 study, his team asked groups of people wearing the caps to look at penguins and try to spot a polar bear in each image. Electrodes in the EEG caps monitored their brain signals and a computer delivered a collective answer. The computer learned to recognise signals associated with each person’s confidence in their decision and gave more weight to confident responses when coming up with the answer – whether there was or wasn’t a polar bear. Perhaps it’s not too much of a stretch to imagine similar technology being used by police officers to search for suspects on CCTV footage or by soldiers assessing warfare scenarios, the only downside being the EEG hairnets and backpacks full of electronics they’d need to wear.

#### PLUGGED IN

The alternative is having electrodes implanted directly in your head, which is what Matthew Nagle did in 2004. Trials of implantable brain-computer interfaces have so far been mostly focused on paralysed people, because for them, the gain in function is worth the surgery and its risks. A quadriplegic, Nagle took the opportunity of a trial to get hooked up to a computer, allowing him, with practice, to control a cursor on a computer screen with his mind, operate a TV and send emails.

Last year, researchers used an updated version of this implanted ‘BrainGate’ interface to give three paralysed people the ability to type up to eight words per minute with their brains. Unfortunately, the current state-of-art for this system requires roughly 100 electrodes and a thick set of cables to be plugged in directly through the top of your skull, risking infection and resembling something out of *The Matrix*. “That’s one of the major issues,” says Prof Thomas Stieglitz, who’s developing brain-computer interfaces for medical applications at the University of Freiburg in Germany. “There are still these ugly connectors that are screwed into the skull and poke through the skin.” Scaling up to a whole-brain interface – à la Neuralink – would require millions or billions more electrodes, which currently can’t be detached from their connectors.

In Freiburg, Stieglitz’s team is trying to build an implant that can suppress the brain signals leading to an epileptic seizure – a step, perhaps, towards widespread use of brain-computer interfaces for the more able-bodied. “Our dream,” he says, “would be that the implant has a program that says ‘Okay, this seems to be a seizure event in six seconds and I know that I should stimulate this part of the brain to interrupt the seizure.’” In fact, he adds, there’s already one ●

“PRIMITIVE VERSIONS OF  
BRAIN-MACHINE INTERFACES  
HAVE ALREADY BEEN USED TO  
HELP PARALYSED PEOPLE  
MOVE PROSTHETIC LIMBS”





● implantable device, a neurostimulator from the company NeuroPace, that's approved as a medical product for this purpose. Meanwhile, University of Freiburg spin-off company Neuroloop is developing a blood pressure implant that stimulates fibres in the vagus nerve that give the brain information about blood pressure. It sends a signal to the brain telling it that blood pressure is too high, triggering the body's so-called 'baroreflex', which can rapidly lower blood pressure via changes in the heart muscles and blood vessels.

At the same time, however, Stieglitz is bogged down in some of the engineering problems that researchers face in creating the early incarnations of these implants – problems that will have to be solved whether we want to cure epilepsy or conduct thought conversations with our friends. “The challenge is to design the system such that it can interact with the human body for an envisioned lifetime,” says Stieglitz. That means finding a way to power it wirelessly inside the skull without having to remove it to charge the batteries, as well as making sure it doesn't damage the nerves that it interacts with or corrode in the watery environment of the body. According to Stieglitz, the latter problem may be tackled by making 'soft implants' that mimic the floppiness of nerve tissue, but it would leave surgeons with a task akin to “implanting a jellyfish”.

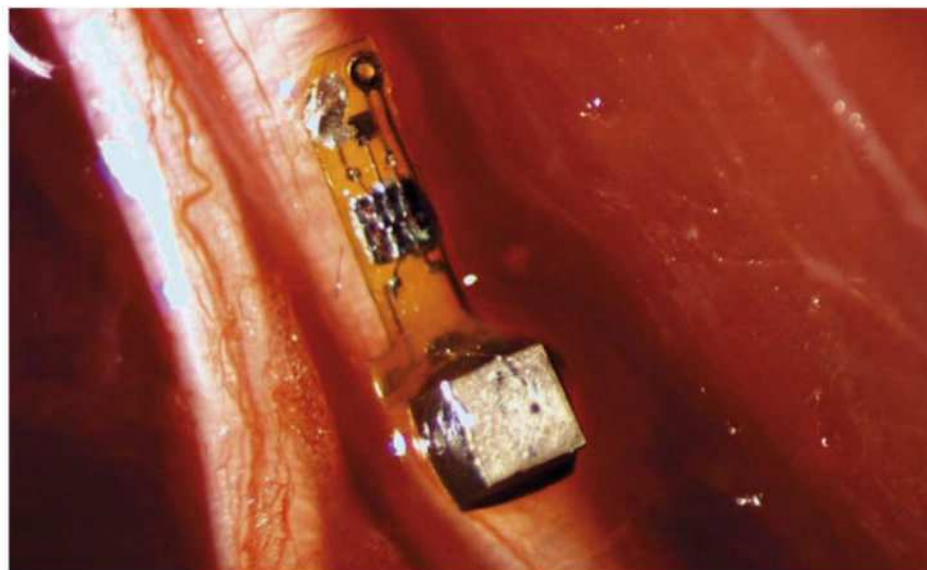
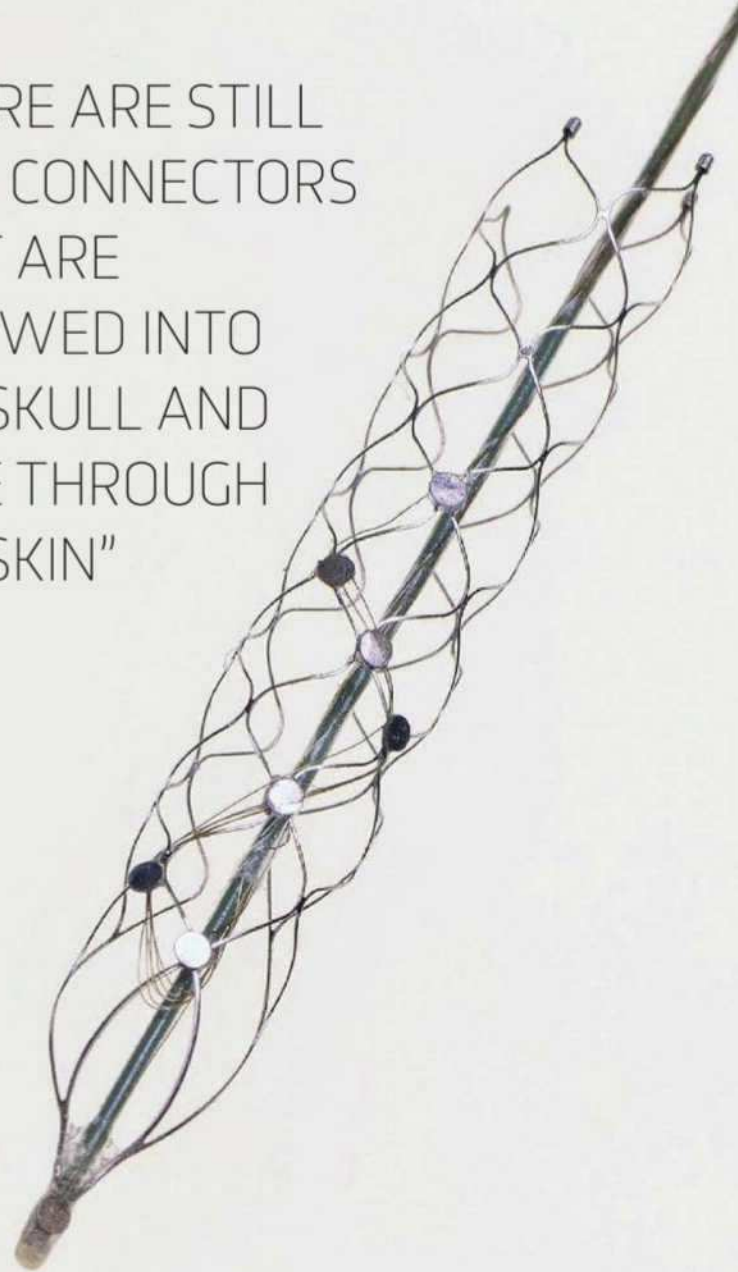
As well as practical issues, there's a minefield of ethical ones with implantable devices. DARPA considers the “burden of surgery” too great and the risks too high for testing in able-bodied soldiers, while Valeriani believes it's better to invest in proven, non-surgical interfaces, which are cheaper. Valeriani admits, however, that placing electrodes on the outside of the skull can't deliver anywhere near the level of detail that would be required for a whole-brain interface. External electrodes only allow neuroscientists to get a general idea of what regions of the brain are saying. Getting an accurate reading from a single neuron requires going inside the brain and that means some major surgery. Or does it?

#### EAT MY (NEURAL) DUST

Five years ago, a team at the University of California, Berkeley, first described neural dust. Today, two of its inventors, Prof Jose Carmena and Prof Michel Maharbiz, are starting a neurotechnology company, Iota Biosciences, developing tiny neural implants that they imagine being installed in a simple outpatient procedure – “in the same way that you get a piercing or a tattoo,” explains Carmena.

Using implants the size of grains of sand, they've shown that they can record and stimulate nerves in rats. They picture a future where we would have a

“THERE ARE STILL UGLY CONNECTORS THAT ARE SCREWED INTO THE SKULL AND POKE THROUGH THE SKIN”



# NEURAL DUST: HOW IT WORKS

LEFT: DARPA has developed this tiny device that can be implanted into blood vessels to record brain activity

BELOW LEFT: A team at the University of California, Berkeley, has implanted this 'neural dust mote' into the nerve of a rat

bunch of neural dust motes implanted to keep tabs on our health via fitness trackers, and treat everything from heart issues to asthma just by tweaking the right nerves. Iota's motes would be wireless and batteryless, potentially doing away with cable connectors and solving the problem of providing power for a lifetime.

But how do you get the implants into the brain without opening the skull? One approach might be to wait until the technology scales down even further, so the motes could be injected, perhaps into spinal fluid. DARPA imagines something similar for its military devices. Its recent document covers nano-sized devices that would be delivered to the brain by "ingestion, injection or nasal administration".

Maharbiz questions whether implants that small could do anything useful. In fact, the Iota pair believe it's possible to achieve "mind-boggling" things without even tapping into the central nervous system. Instead, their dust motes could access the brain via its nerve branches in our limbs and organs, in a similar way to NeuroPace's blood pressure device. "There are other places in the nervous system where we think you can actually put these ports," says Maharbiz. "It won't give you the same bandwidth as having a thousand channels in your cortex, but you'll be surprised at how many things you can do – such as enhancement of your cognitive capabilities – by stimulating these peripheral nerves."

It sounds as if neural dust could be the perfect solution for anyone afraid of a little craniotomy. But could it also

**1** Powered by ultrasound  
Some medical implants are powered by radio waves, but they're unsuitable for tiny implants due to their long wavelength. High-frequency sound waves (ultrasound) have a much shorter wavelength, meaning they're more likely to hit the dust motes. Piezoelectric crystals in the tiny, batteryless implants absorb these sound vibrations and convert them into electrical energy, providing power.

**2** Brain dust  
Neural dust motes could be implanted in the skull by traditional surgical means. Eventually, the motes might be made so small that they're able to receive information from – or stimulate – individual neurons.

**3** Spinal fluid  
This could be a less invasive route into the brain via injections if the neural dust is small enough.

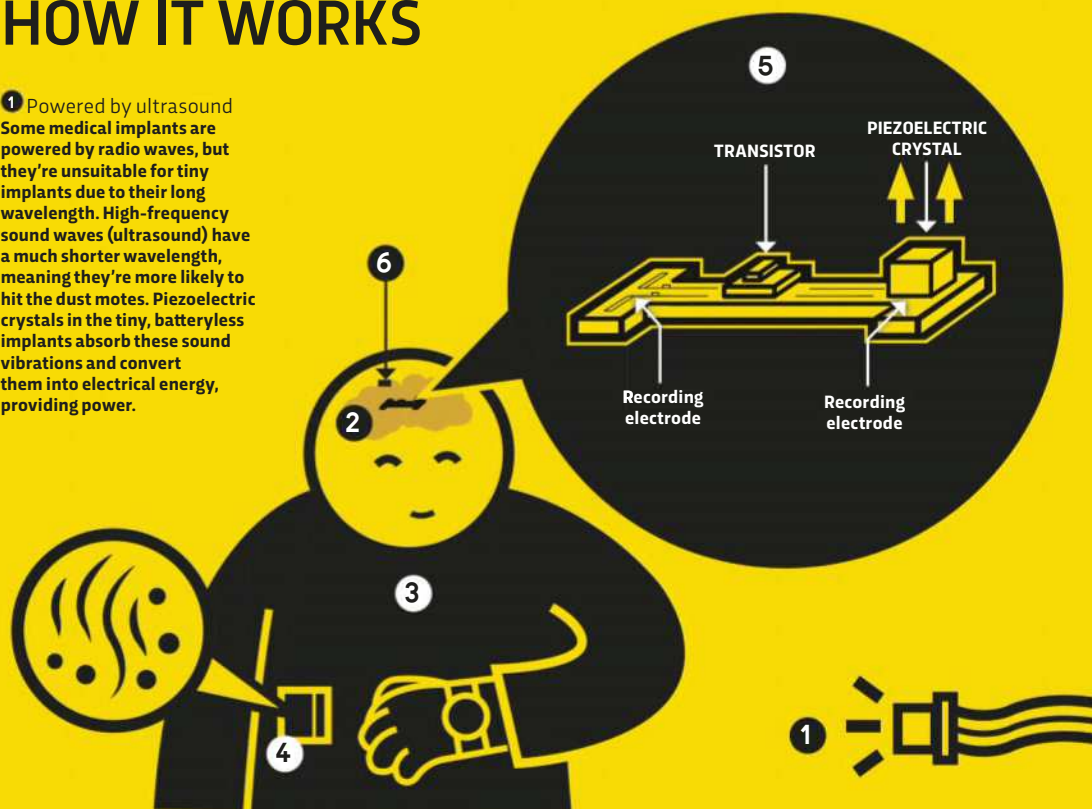
**4** Peripheral ports  
Motes could be installed in parts of the nervous system

that talk directly to the brain, making risky brain surgeries unnecessary.

**5** Wireless communication  
Reflections from piezoelectric crystals carry info to the transceiver so the implants don't need to generate their

own signals, helping keep the devices low-power.

**6** Transceiver  
Provides link between dust motes and your computer, phone or fitness tracker. Could be placed just beneath the scalp or at a peripheral port.



be used to build Elon Musk's dream machine? Can we imagine a whole-brain interface made up of millions of electronic dust motes?

Interestingly, one of the Iota team's collaborators on the original neural dust paper was Dongjin Seo, who now works with Neuralink. While Musk remains uncharacteristically silent on his new project, Carmena and Maharbiz know a few of the team and say there's "no hype at all" in the idea of them building a next-gen implantable brain interface. But regardless of Musk's other ambitions, the first people to benefit will be those with certain medical conditions, says Carmena. "The reality is they're going to build clinically viable devices and we need those by yesterday," he says. "In terms of the use, it's going to be medical for a long time. I can't tell you how long, but it's going to take some time."

So for now, watch this space, but if anyone is going to up-end the world of brain-computer interfaces, you wouldn't bet against it being Elon Musk. **2**

Hayley Bennett is a science writer based in Bristol, UK.

UNIVERSITY OF MELBOURNE, NEUROLOOP ILLUSTRATION: PHIL ELLIS





Enhanced colour image of Jupiter's Great Red Spot, a mega storm that's been swirling since at least the 19th Century



# SO LONG, AND THANKS FOR ALL THE PICS

THIS JULY, JUNO ENDS ITS TWO-YEAR MISSION TO STUDY AND PHOTOGRAPH JUPITER. HERE, WE LOOK BACK OVER SOME OF THE INCREDIBLE SNAPSHOTS THAT HAVE TRANSFORMED OUR UNDERSTANDING OF THE SOLAR SYSTEM'S BIGGEST PLANET

WORDS: DR STUART CLARK  
IMAGES: NASA/JPL

Look out for an episode of *Horizon*, titled *Jupiter Revealed*, coming soon on BBC Two.



**I**n classical mythology, the god Jupiter surrounded himself in clouds to keep his antics hidden from view. Only his wife, Juno, could see through the veil to his true nature. And so it is with the NASA spacecraft of the same name. The secrets of the formation of the whole Solar System lie below Jupiter's all-encompassing clouds, just waiting to be discovered. Theories about our Solar System formation all begin with the collapse of a giant cloud of gas and dust, otherwise known as a nebula, the majority of which formed the Sun. Like the Sun, Jupiter is mostly hydrogen and helium, so it too must have formed early on, capturing most of the leftover material after our star formed. How this happened, however, is unclear. Did a massive planetary core form first and gravitationally capture all that gas, or did an unstable region collapse inside the nebula, triggering the planet's formation? Once processed, the data taken by Juno's instruments will give researchers insights on how the planet formed and what the conditions in the early Solar System were like. But it also carries an instrument called JunoCam, which has taken a raft of images that so-called citizen scientists from the general public can process, and submit back to NASA. The results have been spectacular. ●



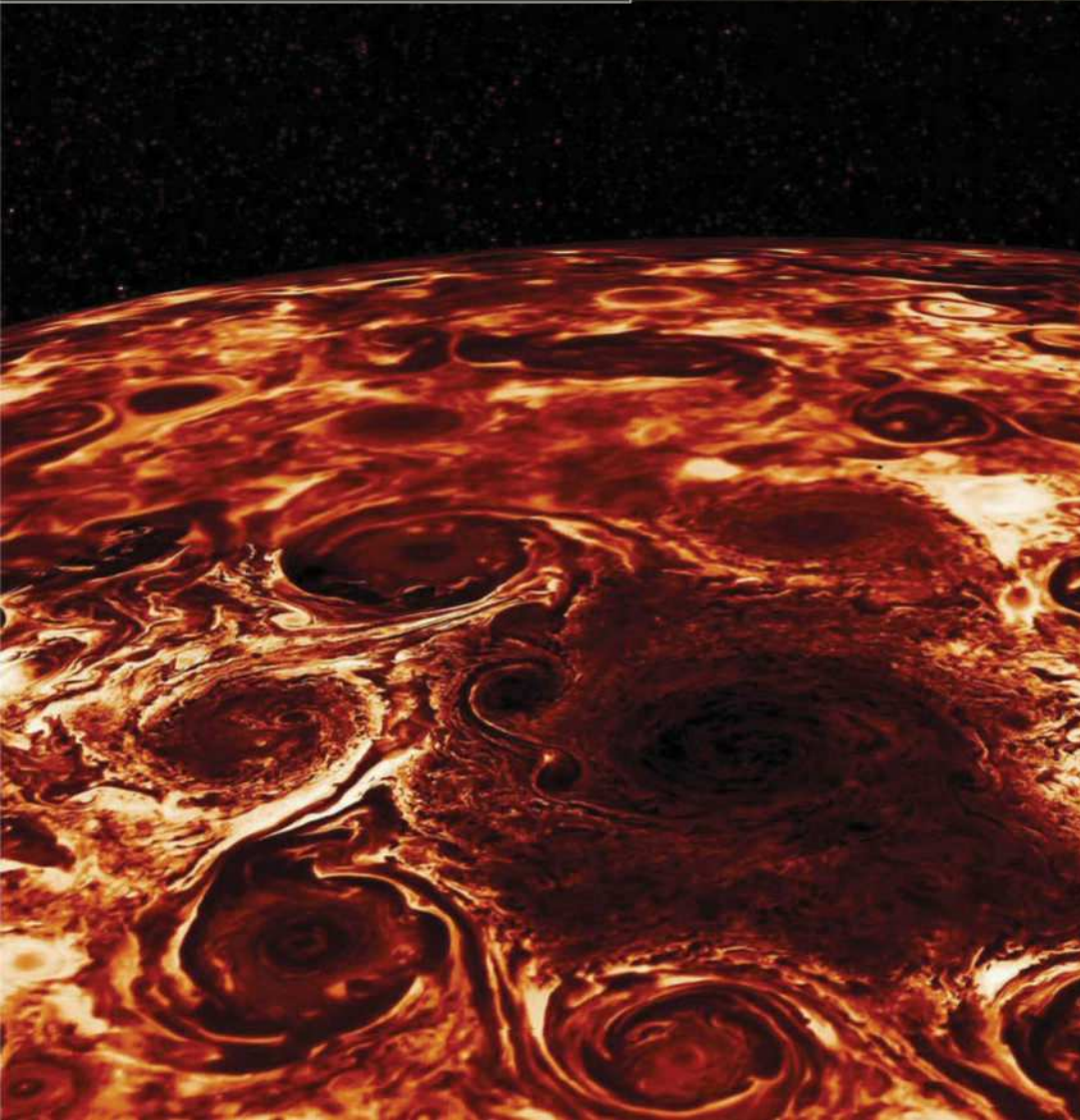
## CLOUDS OF ICE

This raging storm in Jupiter's northern hemisphere was captured during Juno's ninth close flyby on 24 October 2017. The image was taken with the JunoCam instrument and processed by citizen scientists Gerald Eichstädt and Seán Doran to enhance the colours to bring out the details in the clouds. The storm is rotating anticlockwise. The brighter clouds are higher in the atmosphere and catching more light, whereas the darker clouds are deeper down and so more shadowy. In this image, the sunlight is coming from the left-hand side of the image. Both the bright clouds and their shadows measure from 7 to 12 kilometres in length and breadth. They appear to be similar to other bright clouds seen by Juno, so are probably highly reflective due to ammonia ice crystals that are borne upwards on rising currents of gas from deeper within Jupiter's atmosphere. They may also be mixed with crystals of water ice. Juno took this image from a distance of 10,108 kilometres.



## TWISTER

This is what Jupiter's north pole looks like at infrared wavelengths. This composite image has been derived from data collected by the Jovian Infrared Auroral Mapper (JIRAM). These cameras detect temperatures in Jupiter's atmosphere, which roughly correspond to the depth of the cloud features. This image shows the central cyclone at Jupiter's north pole and the eight cyclones that encircle it. Each cyclone is between 2,500 and 2,900 kilometres in width. The colours represent temperatures: yellow shows deeper portions of the atmosphere, which are around  $-13^{\circ}\text{C}$ ; the darkest areas are higher layers that are a frigid  $-118^{\circ}\text{C}$ . Both these regions lie below the visible cloud layer, thus, the JIRAM instrument is giving scientists a way to see into the planet. Finding out how heat flows through Jupiter's atmosphere is vital to understanding the way it works, and provides clues as to how it formed. A key question being investigated is whether the planet has a rocky or metallic core at its centre.







## NIGHT AND DAY

On 7 February 2018, Juno made its 11th close pass of Jupiter. This picture was taken when the spacecraft was climbing away from the planet's south pole, and looking back at the mighty gas world. This particular shot was taken from an altitude of 120,533 kilometres when the spacecraft was almost directly over the planet's south pole. The colour has been enhanced over what would be seen with the naked eye. The line separating the dayside of the planet from the nightside is called the 'terminator'. To capture details in this 'twilight zone', when day is turning to night and vice-versa, the JunoCam instrument took a number of different images with different exposure times. The longer exposures showed the details of the twilight zone but overexposed the daylight side of the planet. The shorter exposures captured the bright hemisphere but failed to show anything near the terminator. Computer processing by citizen scientist Gerald Eichstädt then merged the two images.



## EYES OF THE STORM

Although the Great Red Spot grabs the glory when we think about Jupiter's giant storms, it is just one of many that rage in the planet's atmosphere. This image shows two white storms. It was taken by the JunoCam instrument from an altitude of 33,115 kilometres during the ninth flyby of Jupiter on 24 October 2017, and was processed by Gerald Eichstädt and Seán Doran. The image is more colourful than our eyes would see because it has been enhanced to bring out the details in the atmosphere. The storm at the bottom of the image is part of Jupiter's 'String of Pearls'. This is a series of oval storms, all of them white in colour, that encircle the planet's southern hemisphere at a latitude of 40°. Since 1986, the number of storms has varied from six to nine. There are currently eight of these storms, all rotating in an anticlockwise direction. These vast storms are being powered by heat that is generated in Jupiter's interior.





## JUNO MISSION

### 9 JUNE 2005

NASA selects Juno to become the space agency's next New Frontiers mission.

### 5 AUGUST 2011

Juno launches at 16:25 GMT from Cape Canaveral Air Force Station atop an Atlas V rocket.

### 5 JULY 2016

Juno arrives at Jupiter and goes into a polar orbit that varies in altitude from four million to eight million kilometres.

### 27 AUGUST 2016

Juno completes its first Jupiter flyby. All systems and instruments are working well.

### 19 OCTOBER 2016

Juno is meant to perform an engine burn to reduce its orbit time from 53 to 14 days. Mission managers postpone and ultimately cancel this due to a glitch.

### 10 JULY 2017

During the seventh close flyby, Juno passes over Jupiter's most famous atmospheric feature, the Great Red Spot.

### 16 JULY 2018

Juno's nominal mission comes to an end but the spacecraft is still healthy, so its operational life will probably be extended.

### DATE TBC

Juno will fire its thrusters to decrease its orbit so much that it burns up in Jupiter's atmosphere.

## ALIEN AURORA

This infrared image gives an unprecedented view of the southern aurora of Jupiter. The view is a mosaic of three images taken minutes apart as the craft was pulling away from Jupiter, after its first close approach. From Earth, the planet's southern aurora can hardly be seen. It was captured by Juno's Jovian Infrared Auroral Mapper (JIRAM) on

27 August 2016. Auroras are ovals of light that occur when particles from the Sun strike molecules in a planet's atmosphere and cause them to glow. The auroras appear as ovals because the magnetic field of the planet corrals the solar particles into a cone-shaped funnel that feeds them into the atmosphere around the planet's magnetic poles. The same occurs at Earth, but as Jupiter's magnetic field is the strongest planetary field in the

Solar System – fully 20,000 times stronger than Earth's – its auroras are stronger. This image is composed of wavelengths longer than visible light, ranging from 3.3 to 3.6 micrometres (one micrometre = one-thousandth of a millimetre). These wavelengths were chosen because they are the ones emitted by excited hydrogen ions. These are atoms that have lost an electron particle and dominate the planet's atmosphere.



# THE JUNO CRAFT

**1 JUNOCAM (hidden in this image)**

Takes colour images

**2 GRAVITY SCIENCE**

Studies Jupiter's gravitational fields

**3 SOLAR PANEL**

Three of these power the craft

**4 JOVIAN ENERGETIC PARTICLE DETECTOR INSTRUMENT (JEDI)**

Detects highest energy particles

**5 JOVIAN AURORAL DISTRIBUTION EXPERIMENT (JADE)**

Detects particles and ions that cause the auroras

**6 MICROWAVE RADIOMETER (MWR)**

Measures microwave emissions

**7 WAVES**

Measures radio waves

**8 MAGNETOMETER**

Measures magnetic field's direction and strength all around Jupiter

**9 RADIATION VAULT**

The craft's systems are encased in titanium to protect them from the high radiation levels around Jupiter

**10 JOVIAN INFRARED AURORAL MAPPER (JIRAM) (underside of craft)**

Images auroras in infrared and measures thermal output of Jupiter's upper layers



## ON THE SPOT

If you were to compose a list of the seven wonders of the Solar System, Jupiter's Great Red Spot would be near the top. This gigantic storm system is bigger than planet Earth, and rotates in an anticlockwise fashion with a period of about six days. Although a large circular storm has been reported on Jupiter from the 1660s onwards, it may not be the one we see today. Records are poor between 1713 and 1831 and may indicate that the original storm dissipated, and that the Great Red Spot we see today 'only' formed in the 19th Century. This image is an artistic endeavour based on real data. Citizen scientist Gerald Eichstädt used data from the JunoCam instrument and enhanced the colour to draw the eye into the storm. The raw image was taken on 10 July 2017, during Juno's 7th close flyby of the planet. When the image was taken, the craft was about 10,000 kilometres above the planet's cloud tops. [f](#)

Dr Stuart Clark is an astronomy journalist with a PhD in astrophysics. He tweets from @DrStuClark

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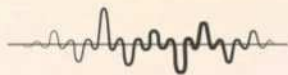
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**FLARES**  
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Flare Audio's **cutting-edge** technology has **earned** the admiration of big names like Julian Lennon, Arctic Monkeys' bass player Nick O'Malley and broadcaster and journalist Caitlin Moran. Last year's award-winning Flares® PRO were a huge success, and now the sound innovator is launching two new sets of earphones that will completely transform the way you listen to music, without breaking the bank – the JET 1 comes in at £49, while the JET 2 costs £69. Here's all you need to know about them.

## NEW TECHNOLOGY

Flare Audio uses the latest technological advances to unveil the true feeling of a song. *"Imagine having X-ray hearing, the ability to hear 'inside' the music,"* is the way Davies Roberts, founder of Flare Audio, puts it. The new JET 1 and JET 2 are ground-breaking because they use actual jet technology, which releases build-up pressure to maximise the front output of the earphone. This lowers distortion levels, giving the JET 1 and JET 2 an audio boost and revealing new details and subtle nuances in your favourite songs.

## NEW SOUND

Experience some of the clearest, most enveloping and immersive sounds, thanks to the high-power 10mm drivers inside each Flares® JET. These create a harmonious symphony where the bass feels unlimited and powerful, but doesn't take over or muffle other sounds. Mid-frequencies are strong and clear, but blend seamlessly with every other frequency, including higher ones, which whisper around listeners rather than overwhelm them. Take DJ and music journalist Pete Paphides's word for it: *"They're easily the best earphones I've ever used. Lovely bottom end, beautiful depth and clarity to the overall sound. It's quite unbelievable."*

## NEW DESIGN

Combining practicality with sleek style, the ergonomic design of Flares® JET means fitting is quick and easy. The JET 1 is made from a high-tensile polymer with a black satin finish, while the JET 2 is made from aluminium using state-of-the-art CNC machinery. Both models include three sizes of silicone tips with superb sound isolation qualities, as well as mic and control capabilities and a branded drawstring pouch.

TO DISCOVER MORE, VISIT [FLAREAUDIO.COM](http://FLAREAUDIO.COM)



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IN ADMIRATION OF MUSIC

**E**very barbecue, picnic and garden party needs a good soundtrack. Even al fresco dining can be improved with some good music to set the scene. Danish high-end loudspeaker specialist DALI has produced a new portable speaker that will satisfy all your outdoor music needs.

The KATCH is the brand's first compact Bluetooth portable speaker. It combines innovative Danish design with the latest audio technology, creating an active loudspeaker that delivers incredibly rich sound from a compact – and super stylish – chassis.

The high-quality audio is the result of a Class-D amplifier, two 21mm soft-dome tweeters, and two 3.5-inch woofers located under the extruded aluminium hood.

This winning combo gives the audio some real punch, but keeps things refined, perfectly balanced and pitched – even at the highest volumes. Plus, the two sound profiles, one for freestanding play and one to reflect sound back

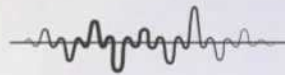
from a wall, mean you can maintain the exceptional audio quality anywhere.

The top-notch connectivity features are endless, and easy to set up. Wireless connection can be achieved within seconds thanks to the Bluetooth with Apt-X, and the NFC (near-field communication) option is even quicker.

Alternatively, you could go for the mini-jack input, or simply use the USB charge connector – handy for linking the KATCH to your home network through a Chromecast Audio dongle. The KATCH also keeps your playlist going for longer, with its powerful 2600 mAh internal battery. Two hours of charge is all it needs to last up to 24 hours, and the power-level indicator lights will warn you when it needs an extra hit.

Easy-to-carry thanks to its leather strap and a protective travel bag, the KATCH is as good-looking as it is smart. It comes in three shades – dark shadow, cloud grey and green moss – with further options coming out later this year. A great centrepiece for any occasion.

TO DISCOVER MORE, VISIT [KATCHSPEAKER.COM](http://KATCHSPEAKER.COM)



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Whether you're at home, at work or on the go, DACs make the sound from smartphones, computers, tablets and laptops infinitely better. In fact, they improve all devices with a digital output, from DAB radios and TVs to games consoles and CD and DVD players, producing greater detail and dynamics. To put it simply, DACs give you more of everything.

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But Mojo is more than just a DAC. This little gadget can be transformed into a fully-fledged music streamer when paired with Poly, Chord Electronics' add-on wireless streaming module, which brings high-quality wireless music streaming to Mojo from a range of connected devices. Wireless devices with DLNA (digital living network alliance) capability are able to benefit from the sound quality improvements offered by Mojo and Poly, which can be app-controlled using smart devices, like phones and tablets. Poly even includes an unlimited-capacity micro SD card slot, so you can compile vast music libraries full of songs ready to be played in optimum quality.

Whichever way you store, access and consume your favourite sounds, thanks to Chord Electronics' award-winning technology, you can enhance your listening experience.



Chord Electronics Ltd.

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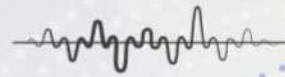
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Say you're recording a podcast, or a video where you're constantly on the move. When you put the headset on, the specially fitted omnidirectional microphones capture the sounds in your environment just like your ears would. And you don't even need a swanky pair of headphones to hear the fruit of your endeavours in full cry; 3D recordings can be enjoyed through any pair of stereo headphones and make you feel like you are actually there listening live. Using Apogee's proprietary PureDigital technology, the AMBEO SMART HEADSET integrates seamlessly with Apple iOS devices – and, of course, it delivers high-quality Sennheiser sound.

- The Smart Slider can adjust the mic sensitivity between normal and loud, whether you're at a big stadium concert or taking a stroll through the forest, with twigs snapping under your feet. This results in a stunningly three-dimensional and immersive sound experience.
- Featuring Apogee's proprietary Soft Limit and mic preamp, plus precisely tuned A/D and D/A conversion, and an Apple MFi-certified Lightning connector, the headset integrates seamlessly with all compatible Apple iOS devices. A version for Android will also be available later this year.
- As well as its unique 3D audio-recording capabilities, the AMBEO SMART HEADSET also acts as a pair of high-quality in-ear headphones. It delivers on the exceptional sound quality you expect from Sennheiser, and provides ultimate comfort thanks to a special ear hook design.
- Its Situational Awareness feature means you can fade the outside noise into your personal programme, which lets you stay safe when you're out and about. If, however, you want pure, undisturbed listening bliss, you can deploy the Active Noise Cancellation.

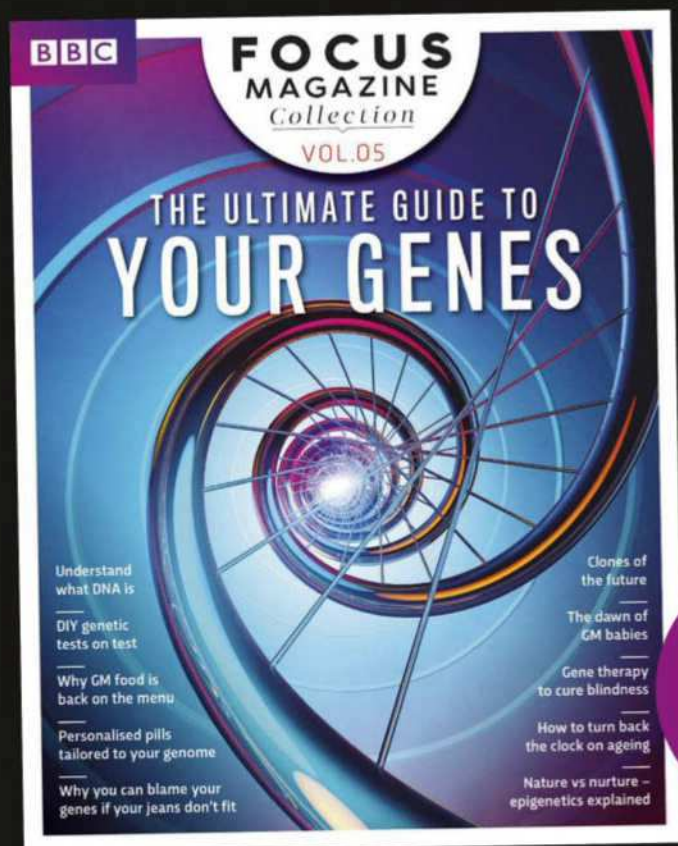
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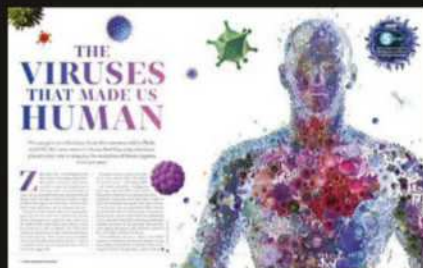
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# YOUR QUESTIONS ANSWERED

JUNE 2018

EDITED BY JAMES LLOYD

## Could we get antigravity from antimatter?

HASSAN BUSHNAG, LONDON

As its name suggests, antimatter is a kind of mirror image of ordinary matter, made up of particles like positrons, with the opposite charge and spin to electrons. ('Spin' is a type of angular momentum that all subatomic particles have, spin can have a value of  $1/2$  or  $1$ .) But most theorists doubt that antimatter also produces antigravity. That's because the so-called charge-parity-time (CPT) theorem of quantum theory suggests antimatter's 'anti-ness' does not extend to its mass and gravitational effect. That said, it's always possible there's a loophole in this theorem: it's had to be tweaked several times over the decades to explain newly discovered phenomena. Later this year, experimentalists at CERN, home of the Large Hadron Collider, plan to look for signs of strange behaviour when particles of antimatter are released in a vacuum. If the particles rise, antigravity may be the explanation. **RM**





## Is there a male contraceptive pill yet?

JASPER WILSON, WISBECH

We're getting closer. Dimethandrolone undecanoate, or DMAU, is still undergoing trials, but initial findings, announced earlier this year, are that it dramatically suppresses sperm production, without the unwanted side effects of previous pills such as breast enlargement, low sex drive or liver inflammation. DMAU is a single molecule, but – like female contraceptive pills – it combines the biological properties of two types of sex hormone. The main ingredient is dimethandrolone, which is a synthetic 'androgen' with some of the properties of testosterone. But DMAU also acts as a 'progestogen'. In men, this suppresses the other sex hormones, such as testosterone and oestrogen, but without feminising side effects. The net result is a drastic reduction in the production of sperm. DMAU also contains the long-chain fatty acid undecanoate, which acts to increase the amount of time the drug spends in the body, so that a single pill will last all day. Turn to p23 for more on the male contraceptive pill. **lv**

## Could the sea ever become too salty for life to exist?

MARTIN SIMPSON, HUDDERSFIELD

The concentration of salt in the Dead Sea is almost 10 times higher than the average for the rest of the oceans. This is far too salty for fish and plants, but even here there are some bacteria and fungi that can survive. The Dead Sea's high salinity is because the water is evaporating much faster than fresh water flows in.

In the open ocean, whatever water evaporates must eventually return. Rivers continually wash more salt in from the land, but the sea has reached equilibrium now, and extra salt just precipitates out of solution onto the ocean floor. **lv**

## What do nerve agents do to the body?

ANDREW ALLAN, COCKERMOUTH

Nerve agents attack the human nervous system. Our bodies use a neurotransmitter called acetylcholine to send messages from our nerve cells to activate muscle and organ cells. Usually, an enzyme called acetylcholinesterase (AChE) clears away the neurotransmitter to allow muscles to relax before being reactivated.

Nerve agents stop AChE from breaking down acetylcholine, so the neurotransmitter builds up and continues to act. Muscles, including those in the heart and respiratory system, are unable to relax and become paralysed, leading to asphyxiation and cardiac arrest within minutes. **ED**



The Dead Sea receives nearly all its water from the Jordan River. In recent decades, some of the river's flow has been diverted, which has led to a drop in the Dead Sea's water levels

GETTY/VS





The microbiome is a hot topic at the moment, and research suggests the diversity of our gut bacteria (pictured) could be linked to our mental and physical health

## What proportion of our bodies is bacteria (and how do we measure it)?

RICHARD ASSELIN, OTTAWA, CANADA

For decades, scientists' best guess was that the body contains 10 times as many bacteria as human cells. However, a team from Israel and Canada revisited the calculations in 2016 to estimate that we have a roughly equal number of bacteria and human cells.

They based their calculations on the fact that most of our bacteria are found in the colon. Using information from MRI scans, they calculated the colon volume of a 'reference man'. Since there are about 90 billion bacteria per gram of wet stool, they estimated that there are around 38 trillion bacteria in the body, compared with 30 trillion human cells. **ED**

## How serious a problem is space junk?

JODIE APPLETON, TAUPO, NEW ZEALAND

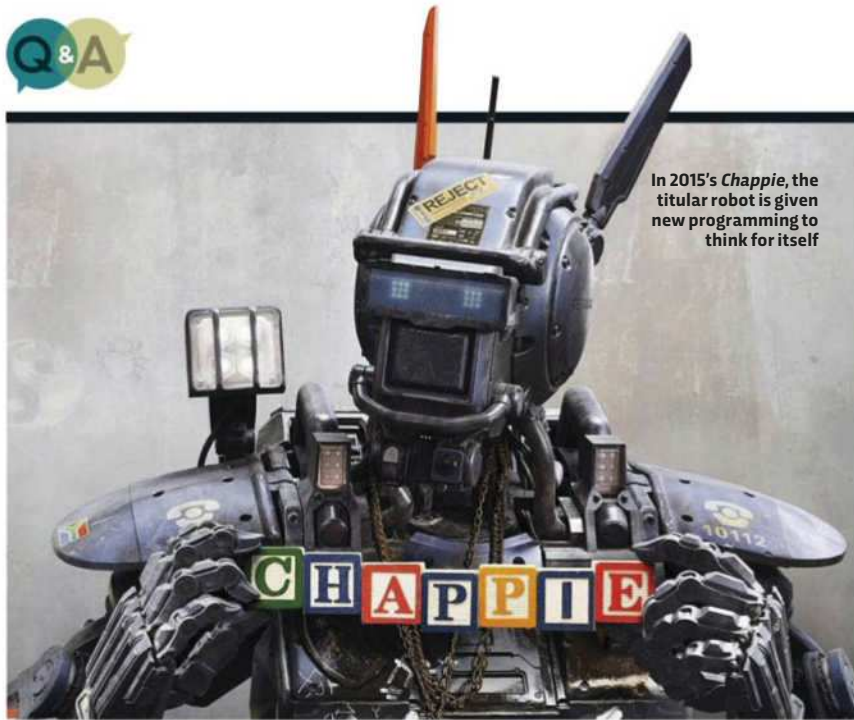
Debris in space, which has been accruing since the 1950s, is a well-documented problem. NASA estimates there are roughly 22,000 objects larger than 10cm in diameter in near-Earth orbit. There are likely tens of millions of smaller pieces, too. Most of this junk is moving at extremely high speeds – up to seven times the speed of a bullet. At that speed, an object no bigger than a penny could easily destroy a spacecraft. Even more worryingly, a 'critical mass' of space junk may be only a few decades away, where one major collision results in an uncontrollable chain reaction, causing untold damage. Possible clean-up solutions include gathering the debris using nets, harpoons, laser beams or mini-satellites, or forcing the junk to burn up in the atmosphere. **AGu**



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In 2015's *Chappie*, the titular robot is given new programming to think for itself

## Does a computer know that it's a computer?

TOBY GRAHAM, SHREWSBURY

Despite all the amazing advances in AI, there's no computer today that understands that it's a computer, and understands what that means. Computers generally know very little about the world – they focus on specific sets of data to solve specific problems. What self-awareness or consciousness would mean for a computer is long-debated, and it's notoriously difficult to create and test. One of the best examples so far was an experiment in the US in which three robots were given a virtual 'pill' which muted just two of them. They were then asked which pill they received. Two remained silent, while one stood up and said "I don't know," quickly followed by, "Sorry, I know now. I was able to prove that I was not given the dumbing pill." **PB**

## Can smart speakers eavesdrop on our conversations?

ALEX PEREIRA (AGE 12)



Smart speakers sit quietly in your room, listening to you all the time. They are waiting for key phrases such as 'Hey Siri', 'Alexa', or 'OK Google'. Once they've heard them, they start recording your voice and upload it to the cloud for processing, so they can figure out what you said. However, the only way a smart speaker can be used to continuously *record* conversations is for it to be hacked, to change its core software. Smart speakers are hardly unique in this sense – most of us walk around with internet-connected microphones as part of our smartphones, which can also be hacked. **PB**

## Why did sleep evolve?

DAVID ABELL, PORTSMOUTH

Scientists disagree as to why sleep evolved. It seems peculiar that we should spend so much of our lives sleeping when it's at this time that our vigilance is at its lowest and we're at our most vulnerable. It's also a time when we don't typically eat, drink, or reproduce. There are a plethora of theories as to why sleep evolved, including the idea that

sleep allows us to save or optimise our energy use and keep us alert to danger. Sleep also allows us to clean toxins from our brains and consolidate memories, and it's increasingly clear that it helps in many aspects of our waking lives, from controlling our weight and regulating our emotions, to bolstering our immune systems. **AG**





## Does the plastic debris found in bottled water affect our bodies?

JANE, DERBY

Almost certainly, although we still don't know how serious the harm is. Tiny plastic particles are essentially ubiquitous in the environment now. A typical washing machine load releases 700,000 particles from clothes fibres, and a 2015 study found that in Paris, 10 tonnes of plastic particles settle out of the air every year. Plastic particles are present in almost all bottled water – and tap water too, though only at about half the concentration. Most of the particles in bottled water are polypropylene, which is used in the bottle tops and is generally regarded as food safe (which means it can safely be used in food packaging). Yet microscopic particles could harbour other contaminants or bacteria. **LV**



Four billion years from now, the night sky could look like this

## If the Universe is expanding, why is the Andromeda galaxy on course to collide with the Milky Way?

BAZRRY CULL, TAUMARUNUI, NEW ZEALAND

The expansion of the Universe is a large-scale phenomenon: in general, the further away a galaxy is, the faster it recedes from us. But over small regions of space, this expansion is negligible compared to the motion of individual galaxies. The Andromeda and Milky Way galaxies are sufficiently large – and sufficiently close together – to create a gravitational force that overcomes the general expansion and pulls them together. But don't worry, the collision won't happen for another four billion years. **AGU**

### THE THOUGHT EXPERIMENT

# WHAT'S THE CARBON FOOTPRINT OF AN EMAIL?



### 1. LESS ENERGY THAN LETTERS

Every email we send uses electricity to display it, and the network connection uses electricity while the email is being transferred. As the email travels across the internet, each server will use some electricity to temporarily store it, before passing it on. Still, sending an email only uses about 1.7 per cent of the energy of delivering a paper letter – but we do send more emails!



### 2. ADD ATTACHMENTS

For a typical email, this electricity is responsible for 4g of CO<sub>2</sub> emissions. If it has a picture attachment, this needs extra storage and takes longer to transmit, so the carbon footprint rises to an average of 50g.

Spam emails are mostly deleted automatically by the email servers before you see them so they don't travel as far and only produce 0.3g each.



### 3. COMPARE TO YOUR CAR

Sending 65 emails is roughly equivalent to driving 1km in a car. In a year, an average person in the developed world adds 136kg of CO<sub>2</sub> to their carbon footprint from the emails they send and receive. This is equivalent to an extra 320km driven in a car. Globally, the world's email usage generates as much CO<sub>2</sub> as having an extra seven million cars on the roads.



## WHO REALLY DISCOVERED?

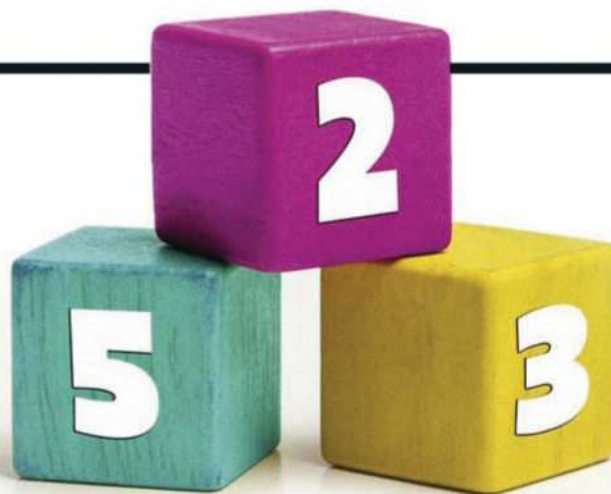
## THE FIRST EXOPLANET

PETER VAN  
DE KAMPMICHEL MAYOR &  
DIDIER QUELOZ

While speculation about planets beyond the Solar System dates back over 2,000 years, actually finding them proved hard – and controversial. During the 1960s, credit for finding the first exoplanet went to Dutch astronomer Peter van de Kamp, who claimed to have found two planets orbiting a nearby red dwarf called Barnard's Star. Based on analysis of tiny wobbles in the star's location over 30 years, the claim stood until the mid-1970s, when it emerged the cause was a wobbly telescope lens, not the effect of invisible planets on the star.

In 1991, two British astronomers claimed to have found a planet orbiting a pulsar, a remnant of a dead star. Within months, this too had been shown to be an illusion. By then, the Polish astronomer Aleksander Wolszczan and colleague Dale Frail had announced the discovery of at least two planets around another pulsar by detecting subtle shifts in its emission of radiation.

While subsequently confirmed, these planets and their parent 'star' have little in common with our Solar System. Credit for the discovery of the first planet orbiting a normal star thus goes to Swiss astronomers Michel Mayor and Didier Queloz, who found a Jupiter-sized object orbiting the star 51 Pegasi in 1995. **RM**



## What's the simplest unsolved problem in maths?

EMILY FRENCH, NEWBURY

If by 'simplest' you mean easiest to explain, then it's arguably the so-called 'Twin Prime Conjecture'. Even schoolchildren can understand it, but proving it has so far defeated the world's best mathematicians.

Prime numbers are the building blocks from which every whole number can be made. All numbers are thus either prime themselves, or can be made from a unique combination of primes multiplied together. When the prime numbers are written down (2, 3, 5, 7, 11, 13, 17, 19, and so on) two patterns emerge. First, they become progressively rare: while 25 per cent of numbers between 1 and 100 are

prime, this falls to just 5 per cent between 1 and a billion. But while they thin out, there still seems to be an endless supply of 'twin primes' like 3 and 5, 29 and 31, 41 and 43, which differ by 2. But do these twins ever run out?

Over 2,300 years ago, the Greek mathematician Euclid proved that primes themselves go on forever. So it seems possible that twin primes might do so too. That's not proof, however – and this remains elusive. Currently, all that mathematicians have managed to prove is that there's an infinite supply of primes differing by no more than 246. **RM**

## Is it possible to 'catch' an accent from someone?

SIMON THOMPSON, LIVERPOOL

If you spend enough time with them, it's almost inevitable. Studies have found that we subconsciously try to imitate speech patterns of strangers, especially if we spend time abroad, where everyone speaks with a strange accent and we are the odd one out. Natural selection seems to have favoured people who have a desire to show empathy and fit in. **LV**



Danish footballer Peter Schmeichel picked up a Mancunian accent, after years of playing goalie for Manchester United





WHAT IS THIS?

**Field of bikes**

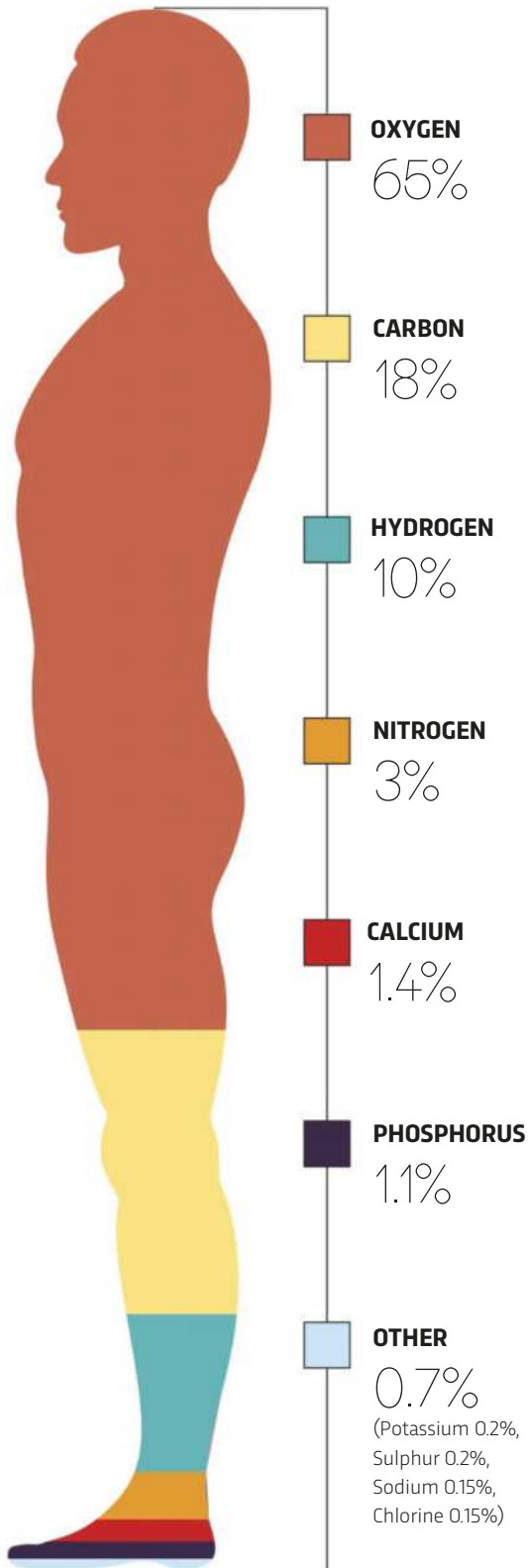
While this resembles a bird's-eye view of rows and rows of tulips, it's actually a field in Shanghai that's filled with thousands of bicycles from bike-sharing start-ups. Many of these schemes launched across China in an effort to reduce pollution and congestion. However, unregulated parking resulted in countless bikes being confiscated, leading to many scenes like this across the country.



## TOP 10

## ELEMENTS IN THE HUMAN BODY

(by proportion of total body mass)



## Why can't we feel atmospheric pressure?

HIYA, RAJPURA, INDIA

The Earth's atmosphere is bearing down on all of us with a pressure at sea level equivalent to around 10 tonnes of weight per square metre. So simply standing upright means carrying the weight of a small car. The reason we can't feel it is that the air within our bodies (in our lungs and stomachs, for example) is exerting the same pressure outwards, so there's no pressure difference and no need for us to exert any effort. **RM**

## IN NUMBERS

44

The number of genetic variants that have been linked to an elevated chance of depression, according to an analysis of 135,000 people with depression.

1,469

The number of bird species faced with extinction. That's about one-eighth of all known species.

43

The age of the oldest known spider. Number 16, a female trapdoor spider, died at the end of April.

## Do babies have nightmares?

MICHELLE BAILEY, DERBY



It's impossible to know for sure, because babies can't tell us! But given the cognitive abilities of babies, experts believe that they do not experience nightmares. Instead, a baby may wake up crying if they're hungry or uncomfortable. They can occasionally appear confused or fearful when aroused from deep sleep. Nightmares typically occur during rapid eye movement (REM) sleep, and are more common later on when the child has developed a richer understanding of the world. **AGr**

# HOW GREEN ARE ELECTRIC CARS?

We teamed up with the folks behind BBC World Service's *CrowdScience* to answer your questions on one topic. You can tune in to *CrowdScience* every Friday evening on BBC World Service, or catch up online at [bbcworldservice.com/crowdscience](http://bbcworldservice.com/crowdscience)



## Are electric cars finally about to catch on?

Manufacturers are now convinced that they can build electric cars with a comparable range and speed to their petrol counterparts. The key is developing cheaper and lighter lithium-ion batteries that can store ever more energy. The technology still isn't mainstream: in the UK, just 1.5 per cent of cars come with plugs. However, in Norway, where there are huge tax breaks and perks like being able to use bus lanes, it's up to 29 per cent. This shows that, with government incentives, people are willing to start driving electrics, and sales are predicted to spike when the price falls to the level of a petrol equivalent – forecast to happen in the early 2020s.

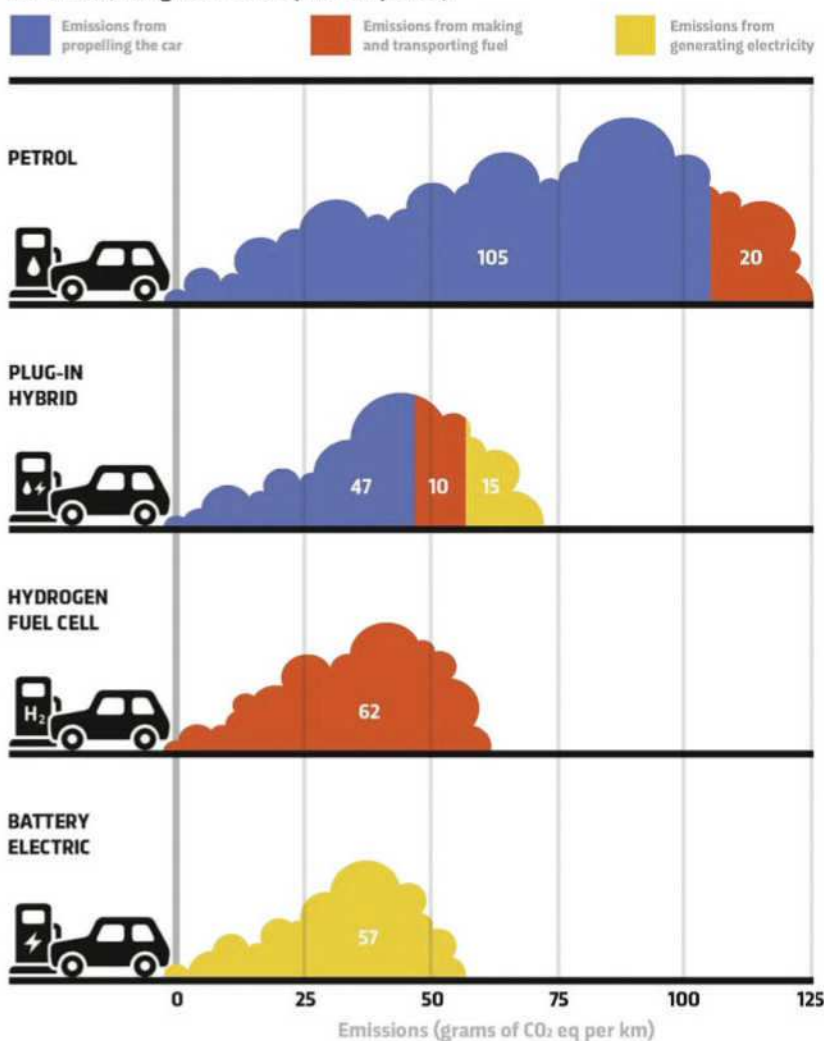
## How do electric cars compare with petrol cars?

The green credentials of your electric car depend on how power is generated where you live. If you have solar panels, then your driving will be free of emissions. If your electricity comes from a local plant that's powered by fossil fuels, then you're just shifting your greenhouse gas emissions from your exhaust to its chimneys. But even in areas with the dirtiest coal-fired plants, electric cars still have lower CO<sub>2</sub> emissions overall. This is because large power stations turn fuel into energy more efficiently than multiple, small engines, and it's easier to clean up the exhaust in their towering chimney stacks. And unlike petrol cars, electric cars will get cleaner if a wind farm or other renewable energy source opens up nearby.

## Are hydrogen cars greener than electric cars?

An electric car with a hydrogen fuel cell instead of a lithium-ion battery offers a compelling prospect: emissions-free driving (the hydrogen combines with oxygen from the air, and the exhaust is water), coupled with fast refuelling. It takes five minutes to replenish tanks of compressed gas, versus at least 40 minutes to top up a modern electric car. Currently, most hydrogen is made from natural gas, which is an energy-intensive process that needs high temperatures. One day, hydrogen could be made via electrolysis (splitting water) using solar-supplied electricity, making it as green as any renewables-powered electric car.

Emissions (total grams of CO<sub>2</sub> equivalent per km)



Figures are from the 2014 EU study /Well-to-wheels analysis of future automotive fuels and powertrains in the European context/, and assume an 'EU-mix' of electricity generation – an average of European energy sources.



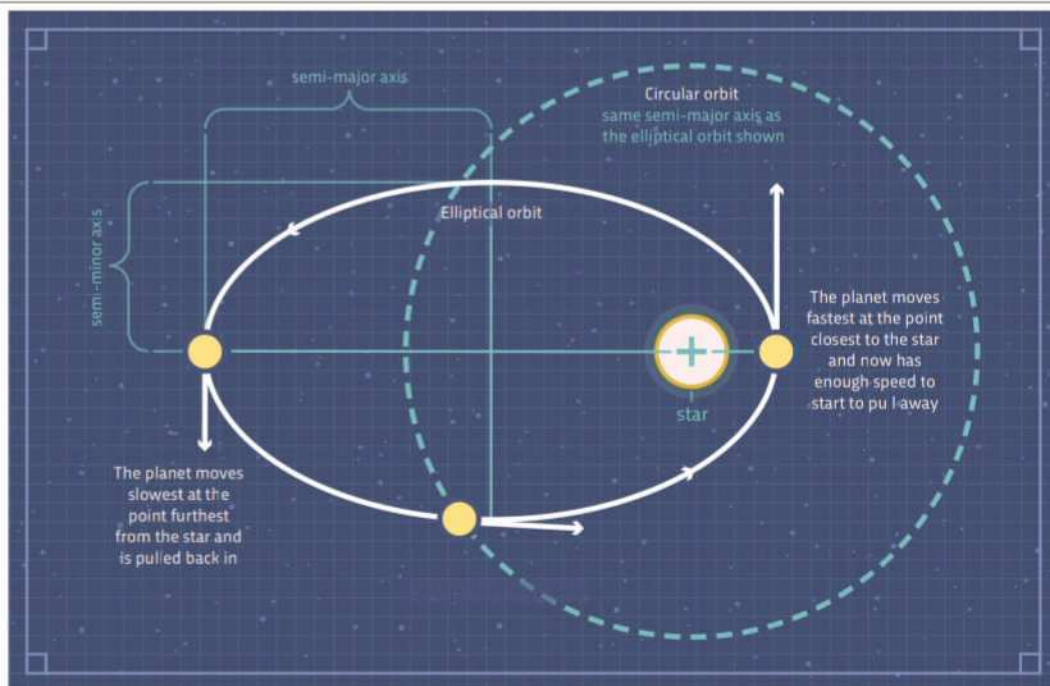
Jack Stewart presents an episode of *CrowdScience* looking at the future of electric cars on 1 June. He also writes about transport for *Wired*.



# Why do objects in space follow elliptical orbits?

ALYSSA S, MAINE, US

The orbit of an object around its 'parent' is a balance between the force of gravity and the object's desire to move in a straight line. If the balance of forces is exact, then we get a circular orbit, but this is rarely the case. Usually, an orbiting object possesses just enough speed to pull away slightly from its parent (but not escape it). This slightly larger orbit causes the orbital speed to reduce, so eventually the object will be moving slow enough to be pulled back in. Hence, the object's distance from its parent oscillates, resulting in an elliptical orbit. **AGu**



## QUESTION OF THE MONTH

### Are some humans more evolved than others?

JOSEPHINE BROOK, LONDON

Evolution is a process, not a property. There are people with genes that give them an advantage in certain environments – for example, some people are more resistant to tuberculosis. In a densely populated city with poor living conditions, that person would be better adapted and more likely to pass that gene on. But that's not the same as being 'more evolved'. If that person moves to a more affluent neighbourhood, or vaccination programs eradicate the disease altogether, then the genetic advantage would disappear.

It's a common mistake to look at animals that have not changed much physically over millions of years and conclude that they are somehow less evolved. In fact, evolution has affected them just as much as every other species. It's just that the forces of natural selection have favoured them sticking to the same design, instead of trying something new.

Humans are certainly still evolving. More recent developments include lactose tolerance, reduced wisdom teeth and blue eyes. And a

large genetic study at Columbia University in New York last year found that harmful genetic mutations that reduce our average lifespan are gradually being eliminated by natural selection. But even long life is only an advantage if we have the civilisation and infrastructure to support us all. **LV**

DNA evidence suggests that blue eyes evolved in humans about 10,000 years ago

### WINNER!

Josephine Brook wins a Nextbase 312 dashcam (£999, [nextbase.co.uk](http://nextbase.co.uk)), which is a *Which?* Best Buy. It records in fantastic quality 1080 HD at 30fps, has inbuilt Wi-Fi to easily download footage and is easy to mount too.



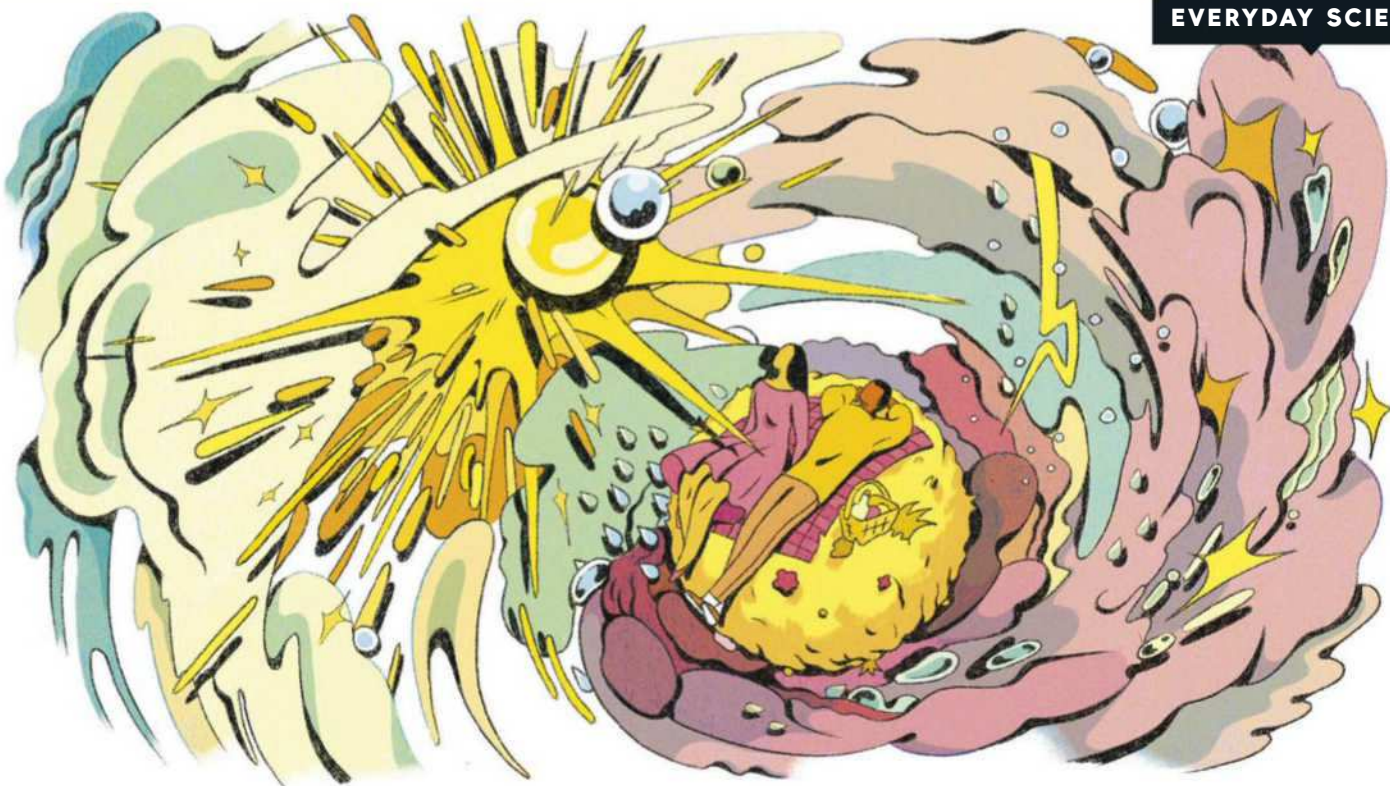
## NEXT ISSUE:

Why are giraffes' tongues purple?

What colour is water?

How do you get milk from nuts?

Email your questions to [questions@sciencefocus.com](mailto:questions@sciencefocus.com) or submit online at [sciencefocus.com/qanda](http://sciencefocus.com/qanda)



## WHY ARE RAINCLOUDS GREY?

**O**nce in a while, it's worth looking up. Our busy lives mean that we're tuned into streets, buildings, cars and kitchens – a rich world

of detail at eye level or below. But we often neglect the vast amount of free space above our heads. Our atmosphere is mostly just air and water, but the visual variety of the sky is astonishing, especially when it comes to the clouds. How does such colour and complexity come from these simple ingredients? The answer is that clouds give us a sneak peek at the optical traffic above our heads – the light that wouldn't normally make it to our eyes.

There is so little to a cloud. They're made of water droplets and ice crystals that are typically a hundredth of a millimetre in diameter, with a few hundred droplets in each cubic centimetre. One cubic metre of puffy 'normal' cloud contains around a quarter of a gram of liquid water. But those tiny droplets of water get in the way of light. Light entering a cloud plummets into an optical pinball machine, scattered again and again by the droplets until perhaps it finds its way out. This process is such an obstacle that you can see through

heavy rain far better than fog, even though there's far more liquid water in the rain, because the larger raindrops have bigger gaps between them.

If white light goes into the cloud, white light will come out. We only see the cloud because it redirects light from the Sun. But as clouds get thicker, it's less likely that light will make its way all the way through the pack and out on the underside, which is why clouds are light at the edges and darker grey underneath.

Then there are those days when the skies darken and we know that rain is due. Raincloud droplets are larger, and potential raindrops are bigger still. Each light ray has to pass through much more water, partly because the cloud itself is thicker. A growing thundercloud might still only have 1.5 grams of water per cubic metre, but it's kilometres tall and light doesn't stand a chance of getting through. Dramatic dark is a fairly reliable indicator that rain is likely.

But it's sunrises and sunsets that really allow the clouds to bask in reflected glory, because the air itself isn't perfectly transparent. Air molecules and tiny particulates will scatter the violet and blue end of

the rainbow, leaving a direct beam made up of reds and yellows. But this filtering is only noticeable at sunrise and sunset, after light has passed through hundreds of kilometres of air as it travels across the sky instead of straight down to Earth. And so at sunset, giant sheets of filtered light from the Sun whoosh over our heads, yellow higher up, with pinks and red lower down, on their way out into the cosmos. This atmospheric party of colour passes us by unless clouds are parked in its way, reflecting the glow. The colours are always there but the clouds curate a shifting exhibition of the sky, letting us in on the secret.

Early summer evenings are the perfect time for appreciating all this. So next time you need a rest from the bustle of life on the ground, I recommend spending a bit of time staring at the sky, where air, water and light are always putting on a show. ☪



### DR HELEN CZERSKI

Helen is a physicist and BBC presenter. Her latest book is *Storm In A Teacup* (£18.99, Transworld).



# OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

JUNE 2018

EDITED BY HELEN GLENNY

## 01 EXPLORE BAGAN

**OPEN HERITAGE**  
FREE  
[ARTSANDCULTURE.GOOGLE.COM/PROJECT/CYARK](https://artsandculture.google.com/project/cyark)

The ancient city of Bagan was once the political, economic and cultural centre of Myanmar, with 10,000 Buddhist temples, pagodas and monasteries dotting the landscape. But the city lies in an active earthquake zone, and today, just over 2,000 of those buildings remain. Thanks to a new project called Open Heritage, you can use your smartphone, tablet, desktop computer or VR headset to fly over or wander through Bagan and

explore its archaeological sites and ancient art. CyArk, a digital preservation non-profit, has collected 3D laser scans and photographic data in over 100 historically significant sites. They've partnered with Google Arts and Culture to create a platform to open source that info, and create models that anyone can experience, starting with Bagan. Over the page, we talk to the man responsible for capturing it.



GETTY







# VIRTUAL HISTORY

Google Arts and Culture has teamed up with digital archaeology non-profit CyArk to give us Open Heritage. Google's programme manager CHANCE COUGHENOUR was on the ground with the team capturing the Bagan Experiment

## How did this project get started?

Ben Kacyra was one of the early inventors of the 3D laser scanner, and in 2001 he saw the Taliban destroy the 1,500-year-old Bamiyan Buddhas in Afghanistan. Ben realised that, using his 3D laser scanners, he could create a digital memory of similarly significant sites that could be used for blueprints, education or restoration. That's what led him to establish CyArk, a non-profit that's been working with governments and universities for a decade, documenting hundreds of sites.

## Why did Google Arts and Culture get involved?

On one hand, we wanted to show the breadth of at-risk heritage sites, but we also wanted to create a platform for CyArk to share their open data and create 3D models of these amazing sites. We want people to learn about the heritage of their countries, how it's connected to other countries and recognise that we're all part of a shared global history.

## Tell us about the Bagan Experiment.

Bagan is one of the most iconic sites in Southeast Asia and has huge significance in Southeast Asian history, with its thousands of beautiful temples. Unfortunately, Bagan was built on a seismic fault. CyArk was working at this site, laser scanning, making 3D models, and creating building plans for UNESCO and local restoration teams when the August 2016 earthquake hit. [Google] recognised the value of their work and helped CyArk return to continue collecting data at the site.

## How does that data collection work?

We use two methods: 3D laser



scanning and photogrammetry. 3D scanning works by shining laser lines over a surface to collect three-dimensional data. The scanners make millions of measurements per second, live. If you set up a laser scanner in different positions around a structure or a building you can then connect those all together to make a 3D model. Photogrammetry involves taking multiple overlapping photographs of the same object or building, taken from the ground and from the air, using drones. Those photos are then processed using computer software to create a photorealistic 3D model. We can combine all of the 3D laser scans and photogrammetry to make high-fidelity, high-resolution 3D models.

## What will we see in the Bagan Experiment?

If someone opens the program on their desktop, they'll see beautiful visualisations of temples. They can fly around the temples of Bagan, they can walk around inside the temples and they can listen to information about what they're seeing while they do it. One of the temples you can visit virtually, Ananda Ok Kyaung, isn't accessible to tourists because of earthquake damage. But through digital preservation you can learn the stories of the incredible floor to ceiling murals that adorn its walls.

If you have HTC Vive, you can explore the temples in high-res VR, or you can see a mobile version of the site on your phone. If you have Daydream or Google Cardboard you can explore by streaming web-VR on your mobile. We wanted to make this accessible to everyone, no matter what tech they're using.



CyArk generating 3D scans of the ancient Mesoamerican city of Teotihuacán

## Three things to do in virtual Bagan:

- Fly through a 3D recreation of the site as BBC broadcaster Bettany Hughes narrates the history and cultural relevance of Bagan.
- Switch off the lights and explore the magnificent Ananda Ok Kyaung temple using your VR controller as a torch.
- Look up at the temple ceilings and admire the intricate patterns that have survived for centuries. The designs are inspired by those found on Indian trade textiles, which were luxury items in Myanmar between the 12th and 18th Centuries.

# 02

## SISTERS OF THE SACRED SALAMANDER

BBC RADIO 4  
TUESDAY 5 JUNE, 11AM

# CHERISH THE AXOLOTLS

A convent of Mexican nuns have become expert breeders of one of the world's most remarkable and endangered amphibians: the axolotl. In a programme for BBC Radio 4, Victoria Gill travels to central Mexico to meet the nuns as they work to make a nearby lake an axolotl-friendly habitat once more. Here are five remarkable facts we learned about these charismatic amphibians:

### 1. Axolotls can regrow limbs, organs and even parts of their spine

Axolotls can regenerate limbs, producing perfect replacements with no scarring. As a result, these salamanders are of great interest to researchers worldwide who study them in the hope of imitating the trick to grow tissues and organs for medical use.

### 2. They feature in Aztec mythology

In Aztec mythology, Xolotl was a dog-headed god who would lead the souls of the dead to the underworld. One account claims that Xolotl was fearful of being killed, so he transformed into an axolotl to hide, which is why the creatures now live in the lakes of Mexico.

### 3. Axolotls are used in traditional Mexican medicine

The salamander is the key ingredient in a traditional remedy for coughs and other respiratory illnesses. In some places, this medicinal syrup is still sold to the public.

### 4. They're normally greenish-brown or black in the wild

This is in total contrast to captive axolotls, which are often white. Most white axolotls are descended from a small group that were caught and shipped to Europe in the middle of the 19th Century, where they were specially bred to be white with black eyes.

### 5. Unlike most salamanders, the axolotl doesn't undergo metamorphosis

Axolotls stay in their early form their whole lives. However, they can be made to metamorphose with a shot of iodine (don't try this at home). They'll transform and end up looking like a tiger salamander, but with spots instead of stripes.





## 03

**CHELTENHAM  
SCIENCE FESTIVAL**  
5-10 JUNE  
BIT.LY/CHELSCIFEST

## CHECK OUT CHELTENHAM SCIENCE FESTIVAL

The *BBC Focus* team can't wait to head to Cheltenham Science Festival for six days of thought-provoking science. These five events are topping our to-do list. See you there!



### Capture-The-Flag: Hacking Challenge

FRIDAY 8 JUNE, 6PM-10PM (AGES 18+)

SATURDAY 9 JUNE, 10AM-12PM (AGES 11+)

If you've dreamed of going underground to become an anonymous hacker, this is your chance to see if you've got what it takes. You'll be working in teams to solve cyber challenges and work your way to the top of the leaderboard. No previous hacking knowledge is needed, as experts will teach you some skills, and you'll use problem solving and logic to crack the challenges.

### Checkmate: How AI Conquered Games And Why It Matters

SATURDAY 9 JUNE, 2PM-3PM

Last year a creative AI program called AlphaGo taught itself how to play chess in four hours. It developed its own strategy, took on the best existing chess-playing computer game, and won. What does that mean for the role of AI in solving humanity's most complex problems? We can't wait to hear Demis Hassabis, CEO of the lab that built AlphaGo, in this panel discussion on the implications of creative AI.

#### AND ALSO...

If you want to take back chess from the hands of super-smart AI, grandmaster Matthew Sadler and Women's International Master Natasha Regan will help you learn some strategies in the **Becoming A Chess Grandmaster workshop**.

VARIOUS TIMES

### Is Your Tech Bad For You?

WEDNESDAY 6 JUNE, 7:15PM-8:15PM

We've all questioned our participation in the tech revolution lately. That's why we're keen to hear online behaviour specialist Adam Joinson and cyberpsychologist Monica Whitty discuss the true implications of our dependence on digital.

### Your Unbelievable Brain: Wine, Sleep and Exercise

TUESDAY 5 JUNE, 7:15PM-8:15PM

This talk suggests we might be able to cleanse our brains with wine! The glymphatic system has recently been discovered (it's thought to be our brain's cleaning service), and with it opens up a raft of questions about how we look after our brains.

### Jury Live: DNA In The Dock

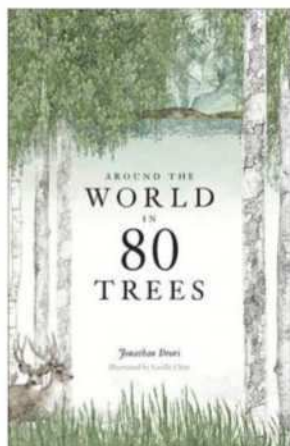
SATURDAY 9 JUNE, 8:30PM-10PM

The verdict in many court cases has hung on scientific evidence. But what would it feel like to be part of a jury in a high-pressure case, faced with complex evidence analysed by both sides? A DNA evidence expert and a criminologist and forensics expert will guide us, the Festival Jury, through evidence collected from two murders, so we can come to a verdict.



#### AND ALSO...

Don't miss the *BBC Focus* Discovery Trail, where you can search for the superheroes of the animal kingdom! Look out for our personal favourite... the naked mole rat. It might not be a looker, but it's a pretty special creature.



## 04 EXPLORE THE WORLD'S TREES

**AROUND THE  
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80 TREES  
BY JONATHAN  
DRORI**

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Trees fascinate scientists with their inventive adaptations, and have offered societies shelter, nourishment and medicine for millennia. Here, tree expert JONATHAN DRORI reveals four of the world's most influential species

### Alder, Italy

In the 12th Century, the Venetians sought to stabilise and expand their marshy home. They saw that alder wood rots quickly in the presence of air but stays intact when submerged. In fact, as long as it remains immersed completely, alder wood will keep its compressive strength for hundreds of years. This is because the chemicals in its cell walls prevent rot-causing bacteria from spreading. The Venetians realised that alder foundation piles could stay strong enough to support great buildings, and they had the monumental chutzpah to turn that knowledge into a beautiful city in a lagoon.

### Chinese lacquer, Japan

The creepiest historical use of the lacquer tree must be that of an obscure sect of ascetic northern Japanese monks, intent on becoming 'living Buddhas' as a route to enlightenment. With the intention of their corpses becoming a 'whole-body relic', the monks gradually embalmed or mummified themselves by drinking urushi tea, made from the sap of the lacquer tree. After becoming horribly dehydrated and dying slowly, their bodies were resistant to decay and too poisonous or unpleasant even for maggots. Three years after death, the monks' tombs were opened and those few who had not decomposed were said to have achieved Buddha-hood.



Tea from the Chinese lacquer tree helped monks on their way to mummification

### Sève bleue, New Caledonia

Through a quirk in geology, New Caledonia's main island, Grande Terre, holds a fifth of all the world's known deposits of nickel. If you cut a sève bleue twig, glistening globules of turquoise appear. Sève bleue means 'blue sap', and an astonishing 11 per cent of the weight of the sticky sap can be nickel, a concentration far in excess of any other living material. While other plants don't absorb nickel from the soil in the first place, the sève bleue uses the nickel as a cheap poison to repel insects that would otherwise eat the tree.

### Neem, India

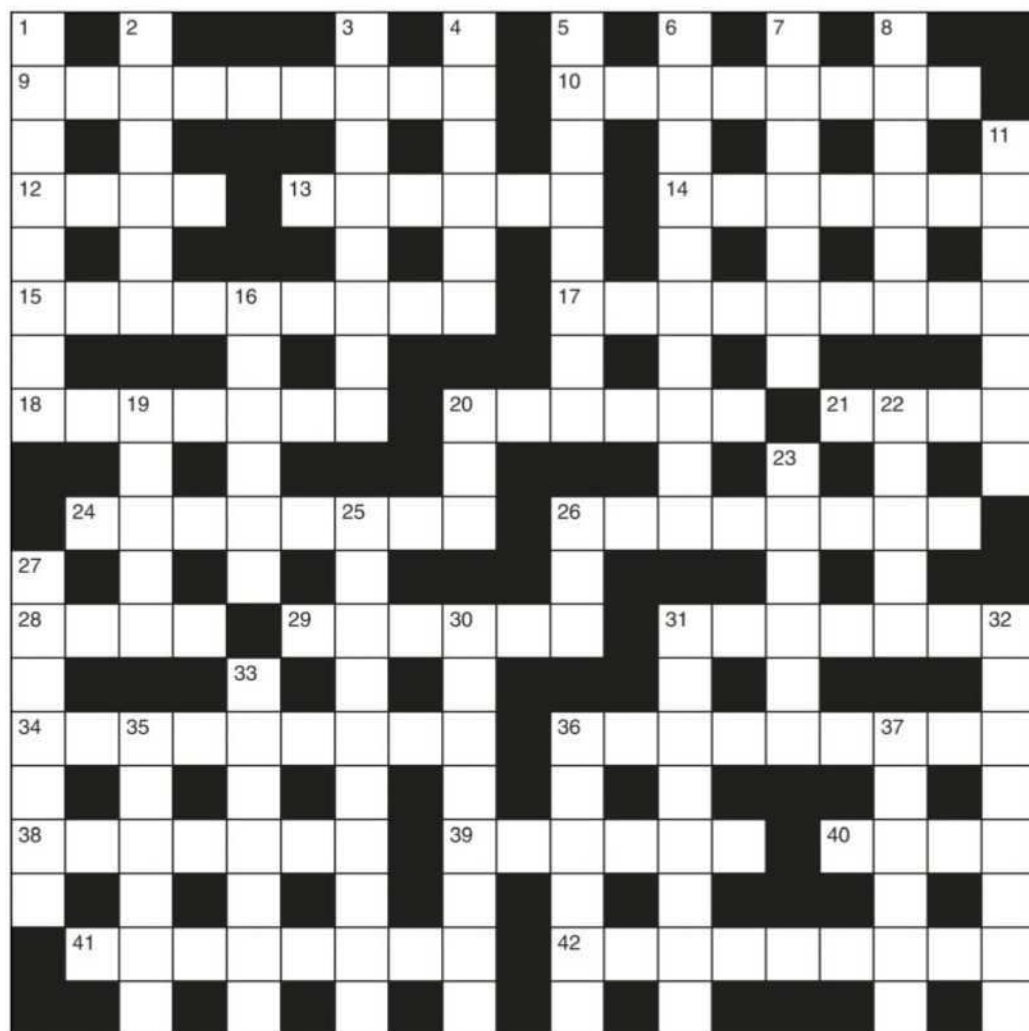
In rural India, neem, with its smorgasbord of antimicrobial properties, is used as a remedy for almost every ill. And its leaves, bark and oil contain a biochemical battery of insect repellents and steroid-like chemicals, which simultaneously disrupt different aspects of an insect's life, making it harder for them to evolve resistance to it. Given this, perhaps the most

perplexing question is why it isn't in wider use around the world. Neem has a long tradition of use, which makes it difficult for commercial firms to patent. Without being able to protect a product from competition, those firms have little incentive to pay for regulatory approval of neem-oil products and can more profitably sell patentable synthetic chemicals. The free market doesn't always get it right.



# BBC FOCUS CROSSWORD

## GIVE YOUR BRAIN A WORKOUT



### ACROSS

- 9** A fellow is a nark – wagging tongue (9)  
**10** Ambiguity about pool sounds complete (8)  
**12** Doctor sees work decrease (4)  
**13** Song about the man (6)  
**14** Pen new melody for deity (7)  
**15** Broadcast a ruling about European getting a pain (9)  
**17** Steer a plan to encourage bonus feature (6,3)  
**18** Girl takes in a mineral (7)  
**20** Last character played game, incorporating universal figure of speech (6)  
**21** First king starts to suspect a university lecturer (4)  
**24** Best 60s group, originally a heavy object (8)

- 26** Bribe gets a blue house (8)  
**28** Repeatedly find unknown old toy (2-2)  
**29** Witchcraft makes firm return with sect (6)  
**31** Wine, endless tea and endless happiness (7)  
**34** Metal left – better than man getting uranium (9)  
**36** Pet heard about large building (9)  
**38** Cat's lip turned out to be artificial (7)  
**39** Rector, old, spills last of last drink in elaborate style (6)  
**40** Mean to change the last word (4)  
**41** Pretend to wear lame suit (8)  
**42** Typically performing with mode, say (2,7)

### DOWN

- 1** Routine enthusiast gets fellow to leave (8)  
**2** Large university pursues improving room in fake gold (6)  
**3** US philanthropist to transport genie about (8)  
**4** A maths problem causes breathing difficulty (6)  
**5** Passion almost gets boyfriend a torch (8)  
**6** Southerner broke Roman's chin (10)  
**7** Punish favourite dog (7)  
**8** Reason to put line in part of sentence (6)  
**11** Leave Pearl running round something in the garden (7)  
**16** Home as starting point, by way of railway (6)  
**19** Welshman takes year finding banned substance (5)  
**20** Rush to find something embarrassing left open (3)  
**22** A charge to see a reef (5)  
**23** Woman takes artist to see a different sort of art (6)  
**25** Time to rent coach out to skilled person (10)  
**26** Chewed on some digital information (3)  
**27** He'll have one eye on endless sequence at work on Sunday (7)  
**30** Put off getting old money – English is relatively dear (8)  
**31** Accent varies – takes notes from dolphin, say (8)  
**32** Wrong license, right part of gun (8)  
**33** Wife sent this to a French festival (7)  
**35** Vitamin is new in CIA operation (6)  
**36** Mad to be seen in front of clock (6)  
**37** Mare ran, getting gold for composer (6)

### ANSWERS

For the answers, visit [bit.ly/BBCFocusCW](http://bit.ly/BBCFocusCW)  
Please be aware the website address is case-sensitive.



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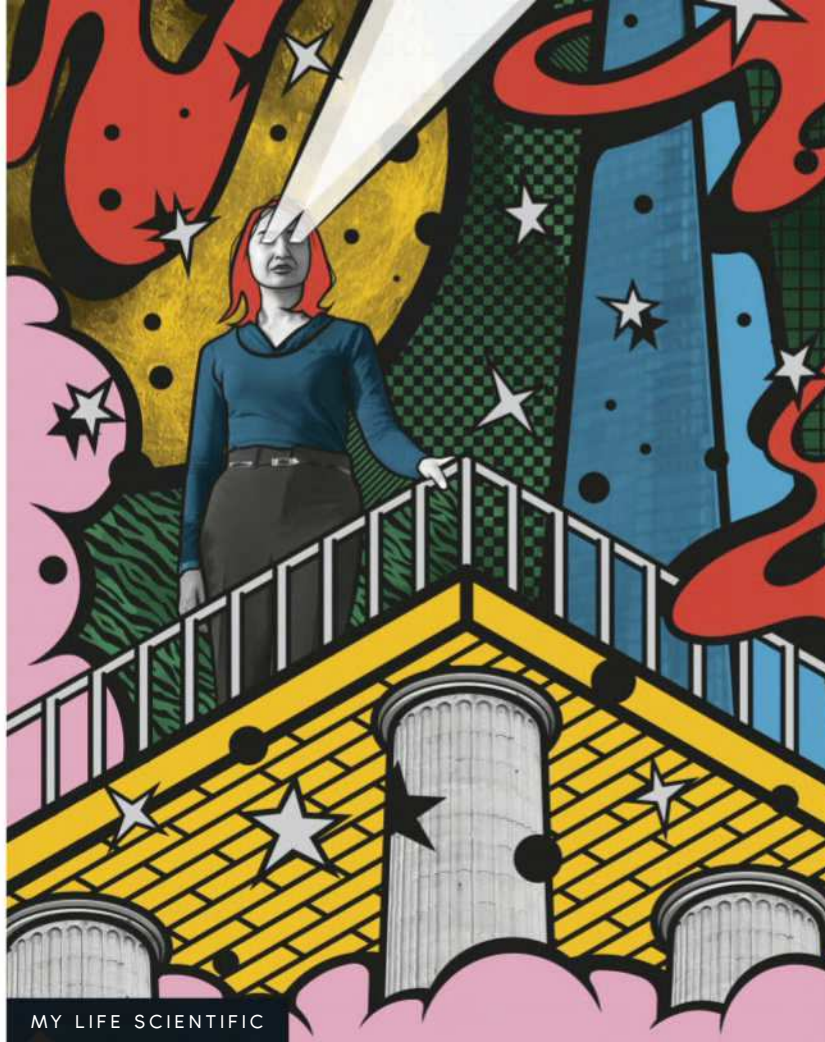
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# Roma Agrawal

This month, **Helen Pilcher** chats with structural engineer **Roma Agrawal** about her love of buildings and why engineers are the world's unsung heroes

Roma co-founded the Your Life campaign to encourage more young people into maths and science, and has spoken at two TEDx talks.

## Why did you become an engineer?

I grew up in India and the US, where my mum was a computer programmer and my dad was an electrical engineer. We had crane sets, Lego and Meccano, and spent every Sunday morning building things. My degree was in physics but I realised I wanted to become an engineer when I did a summer placement and worked with them.

## Which of your projects is your favourite?

The Northumbria University footbridge. It's a lovely little steel bridge in Newcastle that joins up campuses. It crosses a motorway, a bypass lane and a rail track so was quite a complex site. It was great because 18 months after I started working as an engineer, I had a finished project. It gives me a huge sense of pride.

## Didn't you work on The Shard?

I worked on The Shard for six years. I helped prepare the site, design the foundations and engineer the steelwork at the top of the tower. The foundation work was particularly interesting because we used a technique called 'top-down construction', which had never been used before for a building of this height. It meant by the time the foundations were complete, we had already finished 20 storeys of the concrete core of the tower.

## Yet we only hear about engineering when something goes wrong...

The only time I hear the word 'engineering' in public life is when I hear that engineering works have delayed my train, or when something catastrophic happens. It's a shame because engineering is always there, in the background.

Engineers are unsung heroes and we take engineering for granted.

## What's it like being a woman in a sector that is still predominantly male?

When I first started out, I found going to sites challenging. Often, I'd be the only woman there and there'd be pictures of naked women on the office walls. Sometimes, I'd be asked to make the tea and take notes. Since then, things have changed. There's less overt sexism, but biases are still present. I was last mistaken for a secretary just two months ago, when I was being introduced to a director. He looked very embarrassed when he realised his mistake.

## How can we encourage more women?

It's a complex problem. In the UK, only 10 per cent of engineers are women and we lose people at every stage of the school and then career pathway. Every point needs some sort of intervention. In the UK, engineering is not well-known and not seen as something to aspire to. I go out there and tell people about my projects and why I love my job. I'm trying to light a spark of awareness of what engineering is.

## What's your favourite building?

I love the apparent simplicity of the Pantheon in Rome. The Romans knew how their concrete worked and the technicalities of building a dome. Even 2,000 years later, it remains the largest unreinforced concrete dome in the world. I also like Mexico City's Metropolitan Cathedral. The centre of the city has sunk over 10 metres in the last 150 years because it's built on a lake. In the 1990s, engineers did this incredible project to stop the cathedral from sinking unevenly. 

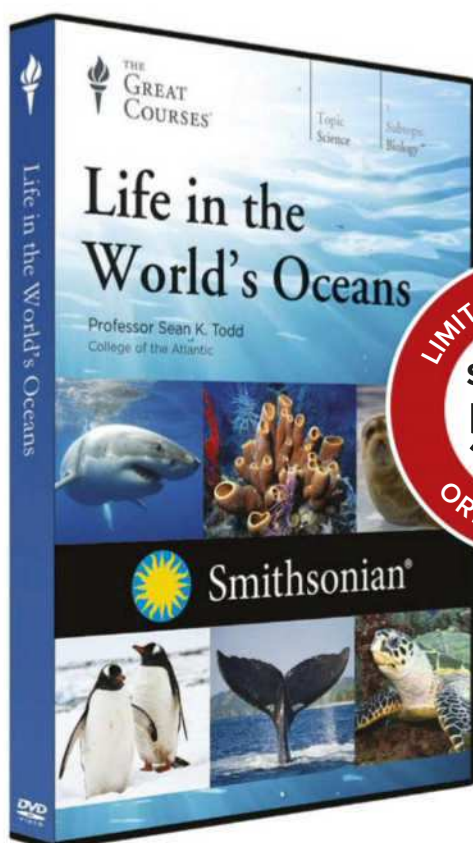
**Roma Agrawal** is a structural engineer. Her book, *Built: The Hidden Stories Behind Our Structures* (£20, Bloomsbury), is available now. She tweets from @RomaTheEngineer

## DISCOVER MORE



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**NEXT ISSUE: GREG WHYTE**



## Experience the Wonder of Ocean Life

The Great Courses has teamed with the Smithsonian to produce a vivid exploration of life in the world's oceans. In 30 lectures, Professor Sean K. Todd, of the College of the Atlantic and one of the world's leading marine biologists, takes you on a journey from the beginning of life four billion years ago to the state of our oceans today. He shares the latest research from the field's most fascinating areas of study, including marine-mammal intelligence and communication; bioluminescence; exploration of the ocean floor; and the Smithsonian's own cutting-edge research work around the world, including the Great Barrier Reef.

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